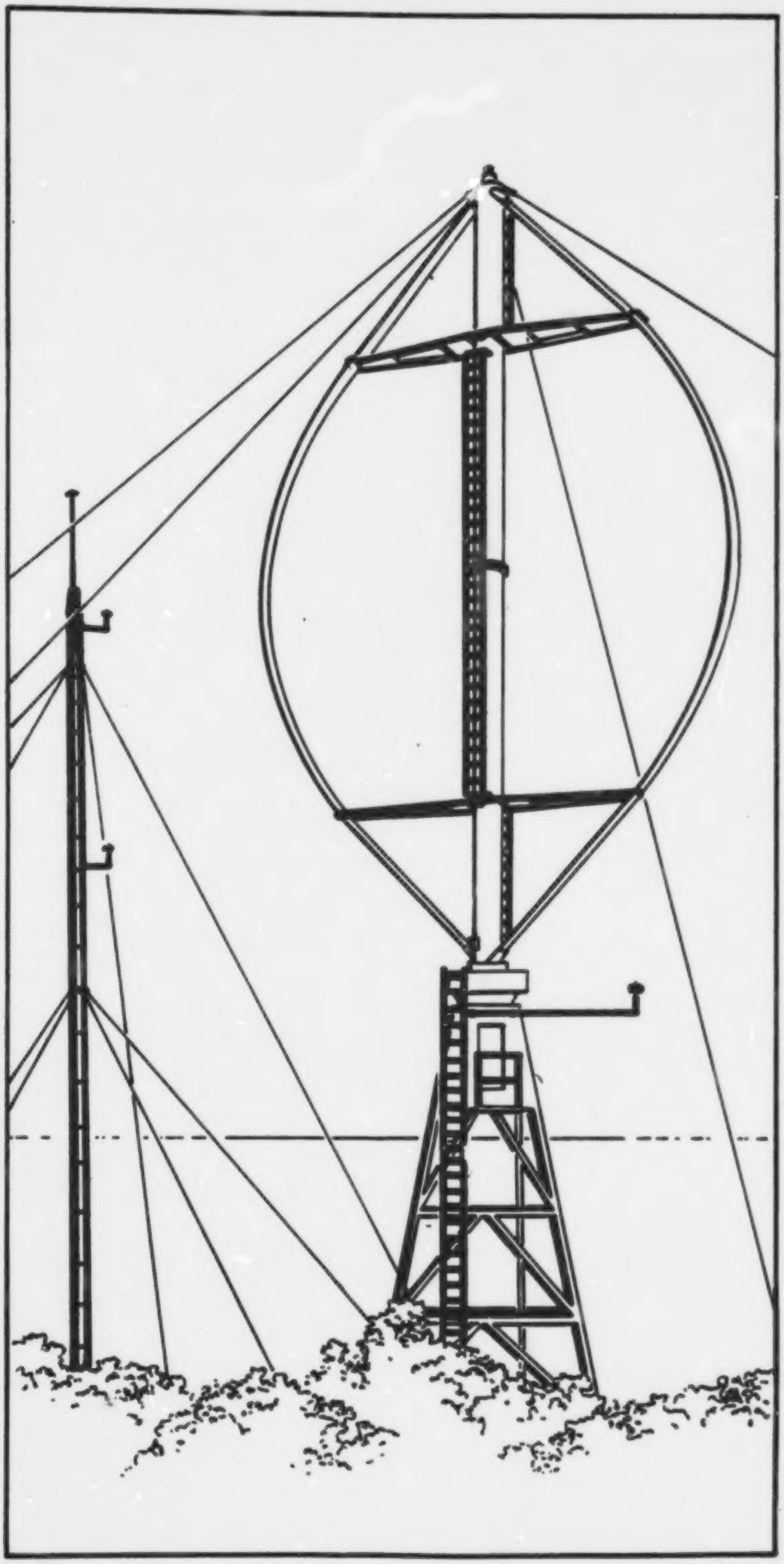

1986 SITE TECHNICAL SUMMARY

VERTICAL AXIS WIND TURBINE AND WIND PROSPECTING PROGRAM

TES Limited
OTTAWA CANADA

T4-W7
86-6129

VERTICAL AXIS WIND TURBINE
AND WIND PROSPECTING SITE
TECHNICAL SUMMARY
FOR 1986
RENEWABLE ENERGY BRANCH

Prepared For:
RENEWABLE ENERGY BRANCH
ENERGY, MINES AND RESOURCES CANADA
Ottawa, Ontario
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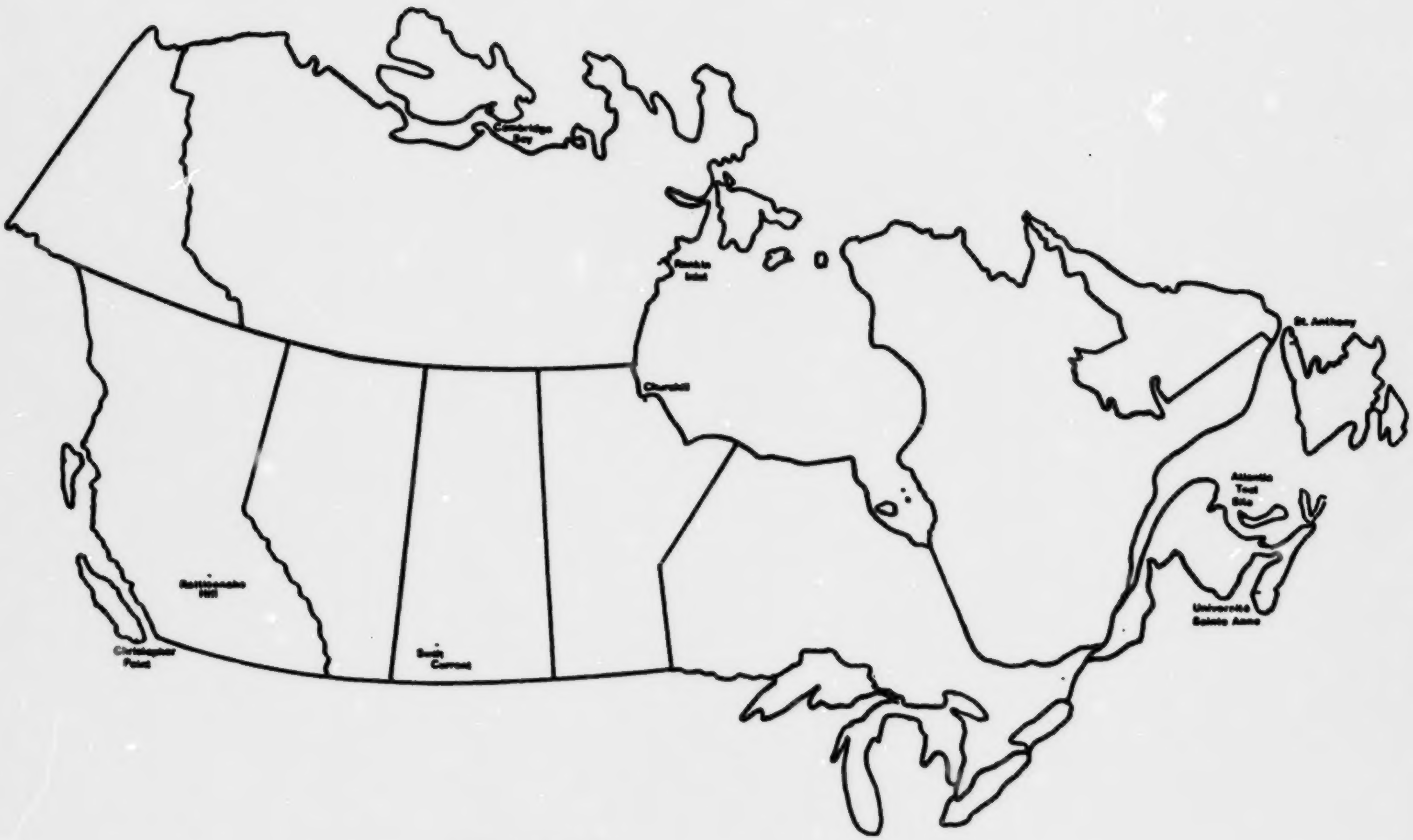

Cambridge Bay
Rankin Inlet
Churchill
St. Anthony
Atlantic Test Site
Université Sainte Anne
Rattlesnake Hill
Christopher Point
Swift Current

SITE LOCATIONS

NOMENCLATURE

Variable Name	Description
P(>)	Probability of wind speed exceeding a given windspeed
V	Windspeed (m/s)
A	Weibull scale parameter
K	Weibull shape parameter
$Z(V)$	Instantaneous rate function
$p(V)$	Probability density function
$R(V)$	Reliability function
$P(V)$	Cumulative distribution function
K_a	Calculated K-value based on full year's data
K_m	Calculated K-vlaue based on individual monthly data
K_{av}	Average of all monthly K_m-values
A_a	Calculated A value based on full year's data
A_m	Calculated A value based on individual monthly data
V_a	Average windspeed based on full year's data (m/s)

NOMENCLATURE (cont'd)

Variable Name	Description
V_m	Calculated average windspeed based on individual monthly data (m/s)
V_{av}	Average of all monthly V_m values (m/s)
p	Standard air density (kg/m^3)
f_{comp}	Air density compensation factor

NOMENCLATURE (cont'd)

Terms used in this report and in the site Performance Summary for VAWT Field Trial data sheets are described below.

NAME	DESCRIPTION
Total Time	Time for the evaluation period based on the calendar and local clocks
Available Time	Time in the evaluation period during which the turbine was available to run and was not shut down for repair or service
Down Time	Time in the evaluation period during which the turbine was not available due to breakdowns, failures or control system trips. DOWN TIME is therefore equal to TOTAL TIME minus AVAILABLE TIME
Run Time	Time in the evaulation period during which the turbine was rotating (i.e. starting up, idling or generating power)
Generate Time	Time in the evaluation period during which the turbine's motor/generator was connected to the line (grid). If we assume that the time taken by the turbine to motor up to running speed is small compared to the GENERATE TIME then we can calculate GENERATE TIME from RUN TIME minus IDLE TIME. Also, the GENERATE TIME may be calculated from the data recorded by the GENERATE ONLY WIND HISTOGRAM RECORDER at the site.

NOMENCLATURE (cont'd)

NAME	DESCRIPTION
Idle Time	Time in the evaluation period during which the turbine was rotating but not generating or motoring (i.e. turbine rotating but motor/generator not connected to the line (grid)). Again, if we assume that the start-up time is small, then IDLE TIME is equal to RUN TIME minus GENERATE TIME.
Approx. Month of Record	Grouping of data by exact calendar months may be approximate in some cases because of actual dates of data recording.
Total Time in Period	Total number of hours in measurement period (calculated from the continuously running Wind Histogram Recorder data).
Average Wind Speed	Calculated from the continuously running Wind Histogram Recorder data.
Available Wind Energy (Betz Limit)	59.3% of the total energy in the freestream wind which passed through the cross-sectional area of a DAF-INDAL 17 m by 11 m VAWT, i.e. 124.7 m^2. (Calculated from the continuously running Wind Histogram Recorder data).
Estimated Generate Time	Amount of time that the wind speed was between the turbine's cutin and cutout wind speed limits (calculated from the continuously running Wind Histogram Recorder data).

NOMENCLATURE (cont'd)

NAME	DESCRIPTION
Estimated Output Energy	Amount of electrical energy that the turbine should have produced assuming no down time. (Calculated from the continuously running Wind Histogram Recorder data and the turbine's performance curve with the specified cutin and cutout wind speeds).
Stop Time	Number of hours the turbine was not turning due to inappropriate wind conditions, but was in a ready state of operation.
Actual Input Energy	The amount of electrical energy consumed by the turbine.
Actual Output Energy	The amount of electrical energy produced by the turbine, as recorded by the turbine's output electrical meter.
Estimated Output Energy Based on Generate Only Histogram Data	Amount of electrical energy that the turbine should have produced based on the "Generate - Only" Wind Histogram Recorder (calculated from the "Generate Only" Wind Histogram Recorder data and the turbine's performance curve).
Actual Output (% of Available Wind Energy)	The overall efficiency of the turbine.
Actual Output (% of Estimated Output Energy with no Down Time)	The operational efficiency of the turbine.

NOMENCLATURE (cont'd)

NAME	DESCRIPTION
Actual Generate Time (% of Estimated Generate Time)	The availability of the turbine.
Down Time (% of Total Time Period)	Down time as a percentage of the total time in the period.
Estimated Output Energy (No Down Time & No Cutout Wind Speed)	Amount of electrical energy that the turbine would have produced assuming no down time and no cutout wind speed (calculated using the continuously running Wind Histogram Recorder data and the turbine's performance curve with no cutout wind speed).

1. INTRODUCTION

The recent interest in developing viable renewable energy sources has led to major research in the area of wind as an alternate source of energy.

The existence of good windy areas, the application of modern technology and analysis techniques to wind energy conversion systems (WECS) has indicated there is a relatively good potential for the existence of WECS in Canada.

The WECS are generally classified as vertical axis or horizontal axis turbines depending upon the rotation of the rotor axis. At present the dominant wind turbine under study by the National Research Council of Canada, Energy Mines and Resources and T E S Limited is the vertical axis wind turbine (VAWT) first patented by George Darrieus in 1927. The Darrieus rotor is a vertical axis, lift type wind machine having generally two rotor blades with an airfoil cross section. Some advantages of this style of turbine include the fact that it is able to operate independently of wind direction, thus not requiring a complex wind directional guidance system, and since the turbine's axis is vertical, the motor/generator and hydraulic equipment may be situated close to ground level, facilitating maintenance.

At present, there is a considerable amount of research required to assess the viability of vertical axis wind turbines in certain areas of Canada. Characterization of wind speed distribution patterns across Canada and evaluation of commercial VAWTs for reliability and cost effectiveness are being carried out. Further investigations should be carried out into the interaction effects among clusters of grid coupled VAWTs and into the development of more accurate models for predicting power and energy performance of VAWTs.

In April 1981 T E S Limited was contracted by the National Research Council of Canada to analyze data on wind speed distribution and VAWT performance from numerous wind prospecting and generating sites across Canada. It is hoped that over a period of several years of continued analysis that major conclusions can be formulated regarding the technical viability of installing VAWTs in certain areas of Canada to augment Canada's future electrical generating capability. In 1986 with the reduction to zero of all energy research and development performed by the NRC Energy Division, Energy Mines and Resources Canada contracted T E S Limited to continue the analysis and reporting of data from the remaining wind prospecting and generating sites.

The instrumentation used for collecting wind regime data varied somewhat among the sites, but in general consisted of an anemometer mounted on a 20 m tower, and an electronic histogram recorder which samples wind speed every 2 seconds and stores the resulting data as counts in bins representing various wind speed ranges. A typical histogram format consists of 64 bins of 0.5 m/sec width covering the wind speed range of 0 to 31 m/s.

The histogram recorders were read by local personnel, typically once per month, and the data were recorded on data sheets which were then forwarded to T E S Limited for analysis on a regular monthly schedule.

Similarly VAWT performance data were recorded by local personnel and the log sheets forwarded to T E S Limited.

The wind regime data received were analysed to characterize the wind parameters for each site, with particular attention being paid to:

1. Wind speed characteristics
   - average wind speed
   - wind speed distribution
   - wind speed probability distribution

- Weibull distribution constants K and A (a measure of the wind speed distribution curve shape)

2. Available wind energy and potential turbine output based on a nominal 50 kW VAWT
   - Betz Limit (a measure of the energy contained in the wind)
   - theoretical generating time possible
   - theoretical energy output possible

In addition, for turbine sites, actual values for energy generated were compared to the maximum theoretical values calculated from the wind speed distribution data.

This report summarizes the data obtained from seven sites for calendar year 1986. Usefullness for some regions may be for seasonal changes only, however, the optimum is for 12 months of continuous data collection.

2. PROSPECTING AND GENERATING SITES

During 1986, seven wind prospecting and four generating sites were in operation. The majority of these sites produced enough data to calculate reasonable annual wind characterization parameters. However, a few sites produced very little monthly data during 1986. As a result, annual figures reported on some sites may not be completely representative of the site's yearly wind parameters. In addition to wind characterization parameters this report deals with the data from each prospecting site as though a 50 kW vertical axis wind turbine was installed at the site.

The procedures for collecting and reporting wind regime data were the same for both prospecting and generating sites. In addition, data describing turbine performance was also collected at generating sites and reported to T E S Limited.

Table 1 lists the site names, the type of site as either prospecting or generating, and the status of each site in this report.

Table 1

Sites monitored during the period of this report

Site Name	Type	Report Status
Christopher Point	generating *	turbine started March 1981
Christopher Point (Middle)	prospecting	summary for 1981-82-83-84-85-86
Churchill	generating *	turbine started November 1981
Churchill	prospecting	summary for 1982-83-84-85-86
Rankin Inlet	prospecting	summary for 1984-85-86
Rattlesnake Hill	prospecting	summary for 1986
St. Anthony	prospecting	summary for 1986
Sainte Anne University	prospecting	summary for 1986
Swift Current	generating*	turbine started August 1980
Swift Current	prospecting	summary for 1980-81-82-83-84-85

* DAF Indal 50 kW VAWT

3. AVERAGE WIND SPEED

As Atmospheric Environment Service (AES) data is tabulated on a monthly/yearly basis, the data from each VAWT station and prospecting site was reduced on a monthly and yearly basis to permit comparison with the closest AES station. The following AES stations were used:

VAWT OR PROSPECTING SITE	AES WIND STATION USED
Christopher Point	Victoria, BC
Churchill	Churchill, MAN
Rankin Inlet	Chesterfield, NWT
Rattlesnake Hill	Ashcroft M, BC
St Anthony	St Anthony, NFLD
Sainte Anne University	Yarmouth A, NS
Swift Current	Swift Current, SASK

4. WIND SPEED DISTRIBUTION

The analysis of histogram data must be comparable from site to site in order to maximize its usefulness. Since the bin boundary definitions and associated bin widths varied in some cases from one histogram recorder to the next, site data were standardized to a common scalar quantity. To standardize the histogram recorder data, the bin count was multiplied by the sampling period and divided by the bin width. This conversion yields a scalar quantity representing the duration of the wind speed in the speed range of a particular bin.

The data representing wind speed distribution was obtained for each site by electronic histogram recorders. Due to the use of different types of anemometer cups (steel or plastic), the bin boundaries varied between sites depending on which type of cups were used. During 1986, all sites used stainless steel cups. A modified grouped frequency distribution (Histogram) was used to facilitate comparison of data between sites. With this type of grouped density distribution, the ordinate no longer represents frequency but a ratio of frequency to the bin width. Thus, by plotting the ordinate as the ratio of time (minutes) spent in a given bin to that bin's width, the resulting histogram will be such that the area of each rectangle is proportional to the class frequency and represents the duration (in minutes) for which the wind speed is within the bounds of the bin.

5. WIND SPEED PROBABILITY

Various plots of wind speed probability can be used to indicate the skew and dispersion of the wind speed histogram. This information is typically used to evaluate or predict turbine performance. With this in mind, wind speed probability was evaluated over the predicted turbine operating wind speed range between the turbine cutin speed (typically 6 m/s) and turbine cutout wind speed (typically 15 m/s).

An analytic probability distribution that has been shown empirically to fit well with a wide range of measured wind speed distributions is the Weibull distribution. This distribution may be expressed in the form

$$P(>V) = e^{-\left[\Gamma(1+\frac{1}{K})\frac{V}{V_{avg}}\right]^K}$$

where $P(>V)$ is the probability (or fraction of the total time) that the wind speed will be greater than any specified value V,

$\Gamma(\;)$ is the gamma function

V_{avg} is the average wind speed, assumed to be at the centre height of the rotor

and K is the Weibull exponent parameter.

The gamma function $\Gamma(\;)$ is normally computed from a sufficient number of terms of an infinite series, but the following curve fit for $\Gamma(1+\frac{1}{K})$ gives values accurate to within one-tenth of one percent over the range K = 1.4 to 4.5 which is likely to cover the range of interest in wind energy applications:

$$\Gamma(1+\frac{1}{K}) = 0.8525 + 0.0135K + e^{-(2+3(K-1))}$$

When $K = 2$ the gamma function reduces to $\frac{\sqrt{\pi}}{2}$ and the Weibull distribution reverts to the special case known as the Rayleigh distribution:

$$P(>V) = e^{-\frac{\pi}{4}\left[\frac{V}{V_{avg}}\right]^{2}}$$

Also by further simplification and reduction the probability distribution P(>V) can be written as

$$P(>V) = e^{-AV^{K}}$$

where A is the Weibull scale parameter which can be determined empirically as shown below, V and K are as previously defined.

Since $P(>V) = e^{-AV^{K}}$

then $\ln(-\ln(P(>V))) = \ln(A) + K \ln(V)$

If the windspeed distribution truly follows the Weibull distribution then, a graph of

$$\ln(-\ln(P(>V))) \text{ versus } \ln(V)$$

should produce a straight line with slope K and intercept ln(A).

Wind histogram data from sites were reduced so as to yield probability [P(>V)] values for each of the 64 bins of the histogram. Each bin represents a small range of wind speeds, about a mid-bin velocity value (V).

These data pairs were plotted with the Y axis representing ln(-ln(P(>V))) and the X axis ln(V). A least squares first order polynomial fit was applied to determine slope and intercept. As previously mentioned, the slope represents the Weibull parameter K and the intercept ln(A).

6. WEIBULL PARAMETERS

If a given frequency distribution can be represented by a Weibull distribution, then the Weibull parameters A and K are sufficient to describe that distribution.

The Weibull parameters are readily related to the instantaneous rate function where K is known as the shape parameter and A as the scale parameter.

The instantaneous rate function Z(V) may be written as

$$Z(V) = AKV^{(K-1)}$$

; V = windspeed
; A = Weibull scale parameter
; K = Weibull shape parameter

or $$Z(V) = \frac{p(V)}{R(V)} = \frac{\text{Probability Density Function}}{\text{Reliability Function}}$$

where $$p(V) = \frac{d\,P(V)}{dV}$$

; P(V) = Cumulative distribution function

and $$R(V) = 1 - P(V)$$

where the cumulative distribution function P(V) is written as

$$P(V) = 1 - e^{-AV^K}$$

then $$R(V) = e^{-AV^K}$$

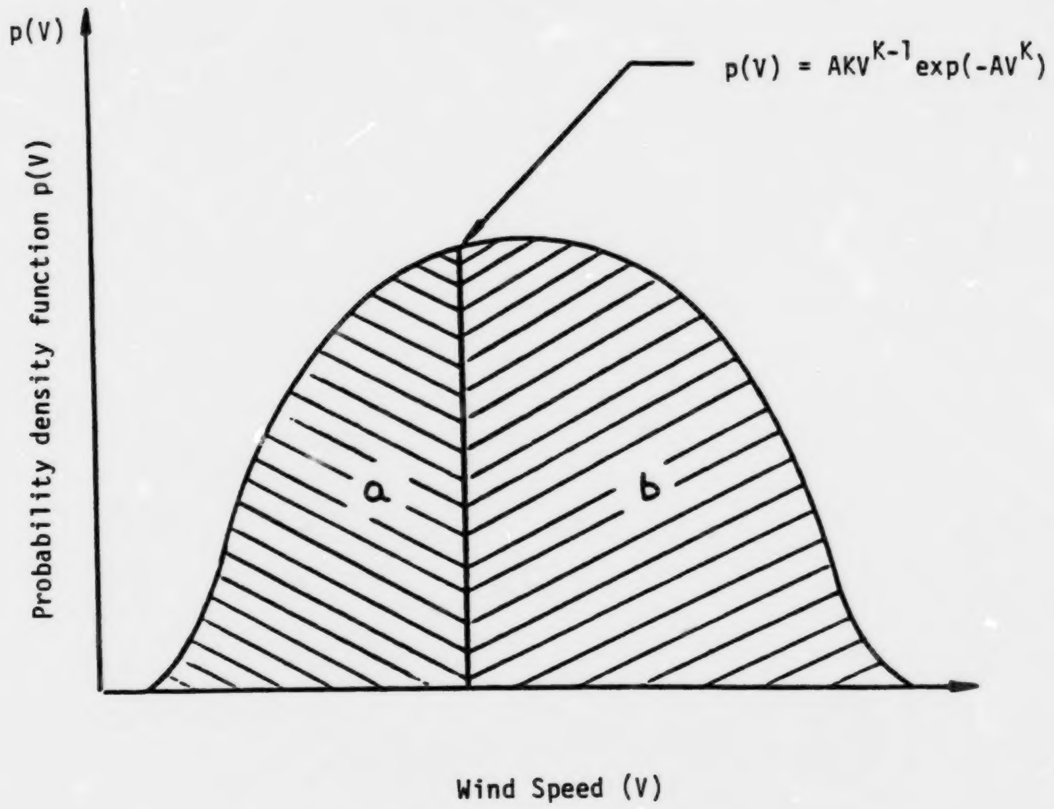
and $$p(V) = AKV^{K-1}\,e^{-AV^K}$$

$p(V) = AKV^{K-1}\ \exp\ (-AV^{K})$ = probability density function

$P(V)$ = cumulative distribution function

$R(V)$ = reliability function

$Z(V)$ = instantaneous rate function



$a + b = 1$

$p(V) = AKV^{K-1}\exp(-AV^{K})$

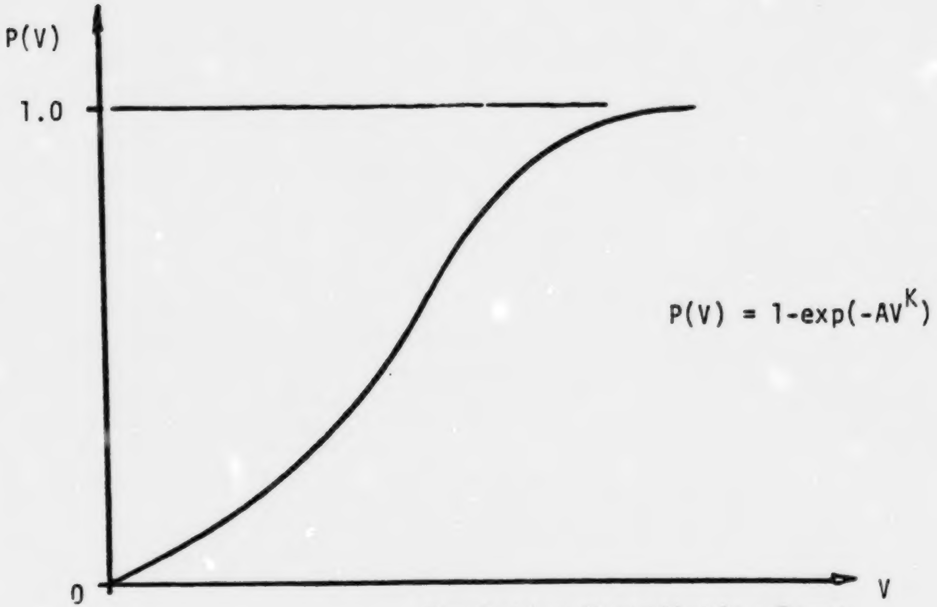
$P(V) = a = \int_0^V p(V)\,dV \qquad = 1 - \exp(AV^{K})$

$R(V) = 1 - P(V) = b \qquad = \exp(-AV^{K})$

$Z(V) = \frac{p(V)}{R(V)} = \frac{p(V)}{b} \qquad = AKV^{K-1}$

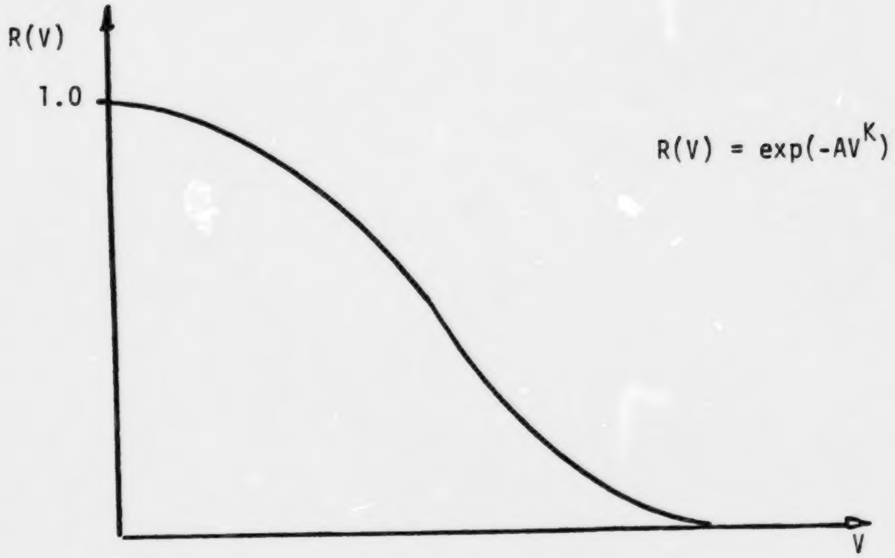
Weibull Distribution Curve

Figure 1



Cumulative Distribution Curve

Figure 2



Reliability Function

Figure 3

6.1 SHAPE PARAMETER

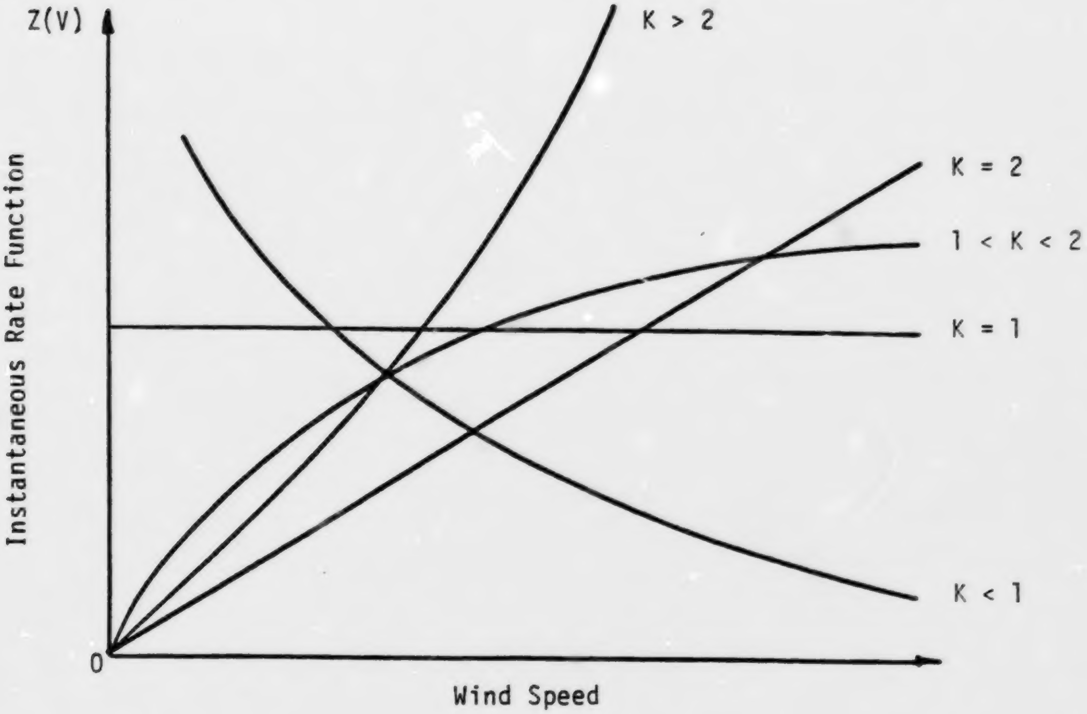
The shape of the instantaneous rate function $Z(V)$ is dependent on K and is related to K by the equation

$$Z(V) = AKV^{(K-1)}$$

Figure 4 below illustrates the effect that the Weibull shape parameter (K) has on the instantaneous rate function $Z(V)$.

for:

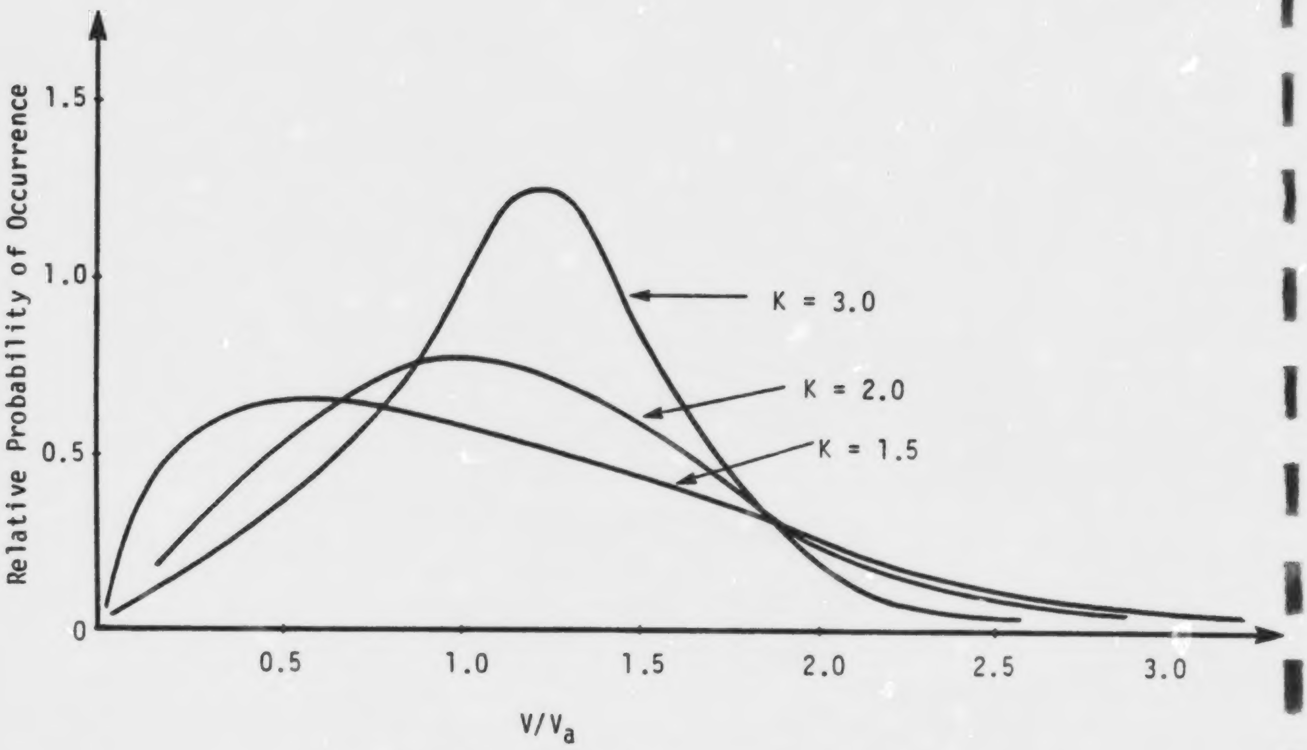
$K > 1$	rate decreases with decreasing gradient
$K = 1$	rate is constant
$1 < K < 2$	rate increases with a decreasing gradient
$K = 2$	rate increases linearly
$K > 2$	rate increases at an increasing gradient



Shape Parameter

Figure 4

Typically, the shape parameter K is a measure of the peakiness of the Weibull distribution around the average wind speed value. High values of K represent relatively steady wind conditions where the most frequent wind speeds are clustered in a narrower range around the average value. Lower values of K represent a more spread out wind speed distribution and usually occurs in regions where average wind speeds are low to moderate. At low values of K the peak of the probability curve is skewed to the left indicating that the most probable wind speed is less than the average speed. Figure 5 illustrates typical distributions for K = 1.5, 2 and 3.



Relative Probability of Wind Speed Weibull
Distribution for K = 1.5, 2 and 3

Figure 5

7. BETZ LIMIT

Comparisons of wind turbine efficiency are often made on the basis of aerodynamic efficiency, which is the ratio of shaft power output to the Kinetic energy flow of the wind through the rotor area. This ratio has a theroetical limit of about 59 percent and is generally known as the Betz limit. Practical wind turbines have maximum efficiencies of typically 40 percent, which is about 70 percent of the Betz limit. As an estimate of the upper limit of power attainable from a wind turbine, the Betz limit can be useful in establishing turbine performance.

The Betz limit is converted into terms of energy when multiplied by operational time. In this report, the Betz limit is referred to in terms of energy with units of kWh. This value represents the maximum energy which an ideal wind turbine with no losses can extract from the wind.

A comparison of the Betz limit with actual energy generated or with theoretical energy generation calculations will yield a measure of turbine efficiency.

Note that available wind energy due to the Betz limit is temperature dependent and consequently any calculation of this available energy must assume a given temperature. It should be noted therefore, that this temperature may not match the fluctuating temperature of actual operating conditions. In this report, the temperatures used for the available energy due the Betz limit calculations were monthly/yearly averages obtained from AES data.

8. TURBINE THEORETICAL ENERGY GENERATION

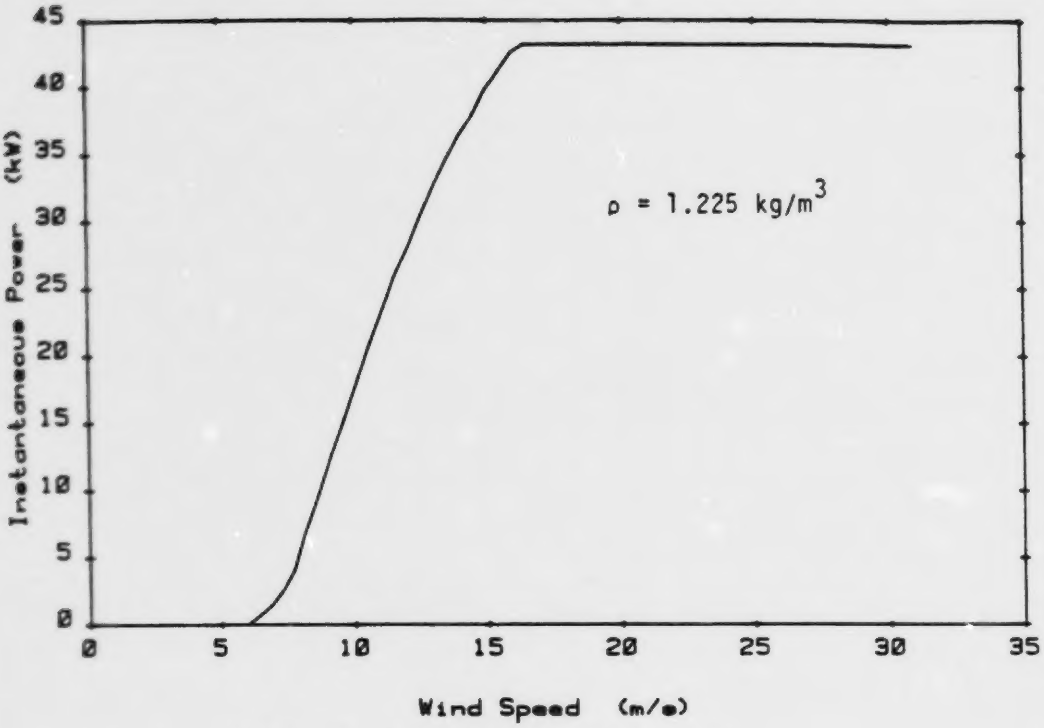
During 1985, there were four operational vertical axis wind turbines. The necessary power curve for each turbine was supplied by NRC staff. Theoretical energy generation was calculated using these power curves and the site monthly/yearly wind histograms. For comparison purposes, theoretical energy was calculated and plotted for various operational speed ranges with the actual energy generated by the site. The actual energy generated was recorded at each site by kilowatt-hour meters.

Since no time domain information is contained in the wind histograms, even with accurate turbine power curves, the theoretical energy generation calculations may still contain some degree of error.

The suitability of the turbine power curves used in this report for predicting turbine performance under operational conditions is still under study.

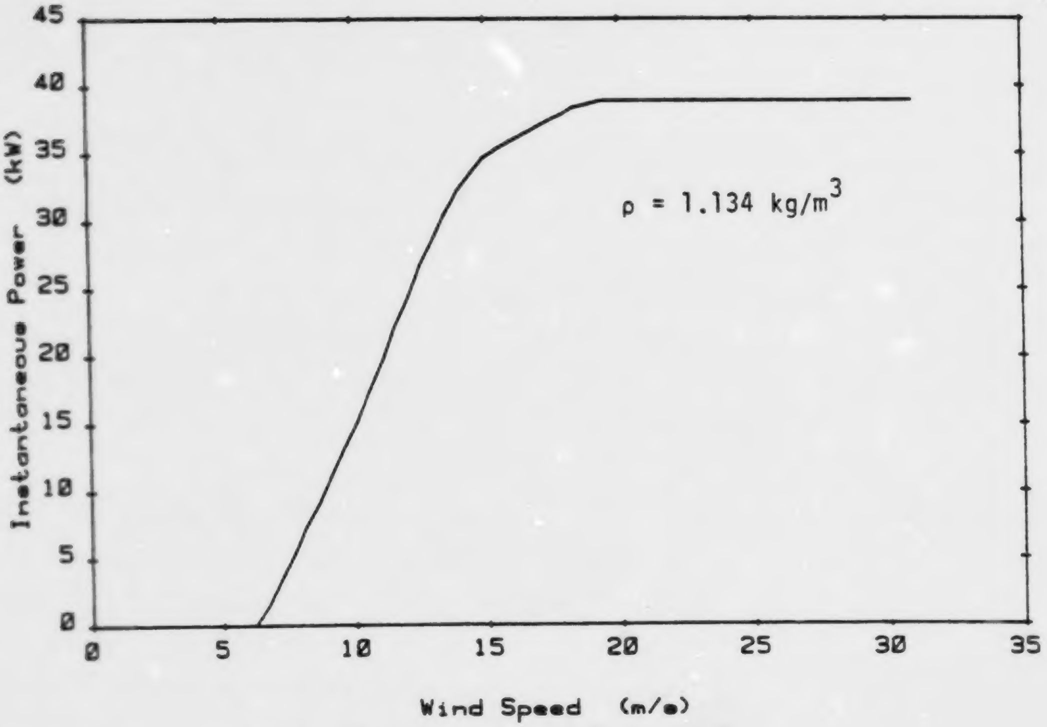
Figures 6, and 7 are reproductions, extracted from the manufacturers' data, of the turbine curves presently being used to calculate the turbine theoretical energy output.

A measure of the accuracy of the turbine power curves may be made by comparing theoretical energy generation with the Betz limit and the actual power generated. Note, however, that for an accurate comparison to be made, the theoretical energy calculation should account for the turbine efficiency and control system design including the cutin and cutout wind speed settings.



Turbine Power Curve for 50 kW VAWT
(Christopher Point, Churchill, Holyrood)

Figure 6



Turbine Power Curve for 50 kW VAWT
(Swift Current)

Figure 7

9. DISCUSSION

The following paragraphs discuss major areas of interest concerning VAWT field trials and wind energy data analysis performed by T E S Limited.

9.1 Annual Average Wind Speeds

Two different methods of calculating the annual average wind speeds were used in this report.

V_{av} The average of the monthly-average wind speeds was determined.

$$V_{av} = \frac{\sum_{s_m}^{e_m} V_m}{n} \text{ m/sec}$$

where s_m = startup month of recording period
e_m = end month of recording period
n = recording period in months

The accuracy of this measurement depends on the accuracy of the monthly wind speed histogram. The reader should be aware that corrections were made to the monthly wind histogram in cases where the histogram data were obviously in error due to a histogram malfunction or operator reading error. Any such corrections were identified by footnotes on the respective Site Performance Summary Sheet.

V_a The annual average wind speed was determined from the annual wind speed histogram. Corrections made to the monthly histogram data were carried forward through to the yearly histogram. As can be seen from Tables 3, 4 and 5, the difference in the results of the two methods of calculation is not great.

9.2 Annual K-Value

The annual calculated K-value (K_a) should not be confused with the average of the monthly K_m values (K_{av}). Each was calculated differently and describes different characteristics of the wind speed profile data.

K_{av} The annual average K_{av} value is the average of the K_m values which was determined from the monthly histograms.

$$K_{av} = \frac{\sum_{s_m}^{e_m} K_m}{n}$$

where s_m = startup month of recording period
e_m = end month of recording period
n = recording period in months

This annual average with its standard deviation may be used to describe the seasonal fluctuation in the wind speed distribution.

K_a The annual calculated K_a value is based on the annual histogram (sum of the monthly histograms) and thus should be used to describe the annual wind speed distribution and the annual wind energy.

9.3 Sample Size of the Data

Any effort to predict or evaluate turbine performance based on the information presented must be tempered with the knowledge that this report, in many cases, describes only one cycle of the seasonal variation of the winds at each site. This sample size may not be large enough to accurately show long term trends. The site with the largest sample size was Swift Current, where wind speed distribution data has been collected for almost 6 years.

9.4 The Effects of Different Time Periods for Each Monthly Report

Histogram recorders were not read every day. (In most cases the recorders were read once a week or less.) Thus, data reduction could not be performed from the beginning to the end of every month. Therefore, the time period of each monthly data reduction varied from site to site and month to month. No direct comparison between sites' performance can be made unless the time period is taken into account.

The magnitude of all the energy measurements and calculations is dependent on the time period over which the measurements or calculations were made as well as the shape of the wind speed profile. An increase in one of these parameters may be the result of higher winds or a longer measurement period.

It may be interesting to note the effect caused by the differing wind speed profiles. This effect may be obtained by dividing each parameter of interest by its associated time period. The time period is recorded in column 2 of the Site Performance Summary Sheets in the Appendices.

9.5 Turbine Output Energy

Since any evaluation of the net turbine output energy must take operational time into consideration, the data sheets include entries for down, stop, idle and generate times, and actual input and output energy for sites where these data were monitored. Another measure of turbine availability can be obtained by comparing Columns 6 and 11 of the site data sheets found in the Appendices. Column 6 in the data sheets shows the time that the wind speeds were within the operational range of the turbine. If the turbine was operating well, this time period would be similar to the actual generate time (Column 11). A ratio of these two numbers is expressed as a percentage in Column 17.

When the turbine is operating 100% of the estimated generate time, its energy output can be compared to the theoretical energy calculations.

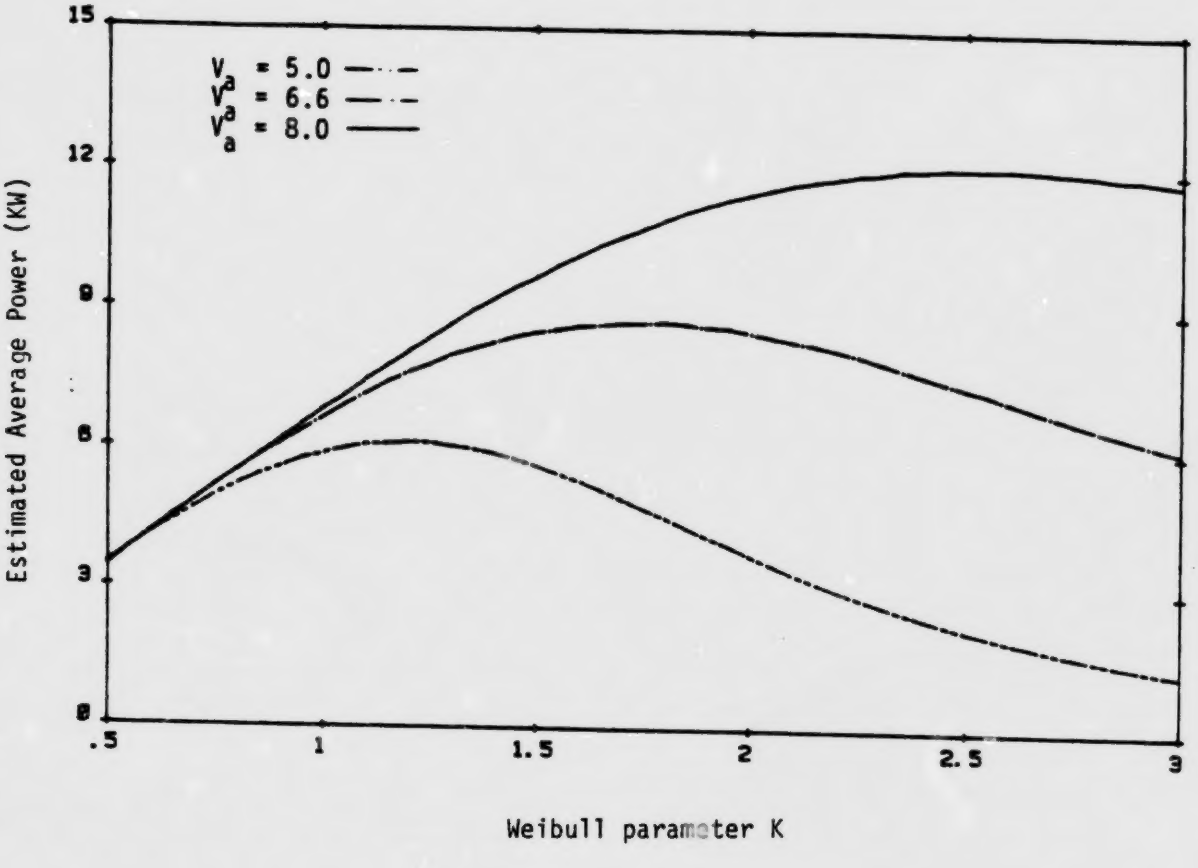
9.6 The Effects of Average Wind Speed and Weibull Parameter K on Theoretical Energy

Since lower values of the Weibull shape parameter K, indicate that for a larger proportion of time the wind speed was within the upper regions of the turbine wind speed energy profile, then, for a given mean wind speed and low K-value, it could be suggested that more energy could be produced from the wind.

Also, for a given value of K, higher average wind speeds would indicate larger quantities of energy in the wind.

It appears that for values of K above approximately 1.6 there is little time where the wind speed is in the vicinity of the cutout wind speed. Thus, calculations using various values of cutout wind speed will yield similar results for the theoretical energy. For wind speed Weibull distributions, where the K-value is below 1.6, there is a significant time when the wind speed is at or above the cutout wind speed. For these distributions, significant energy could be derived with an increase in turbine cutout speed. This may be evaluated by comparing graphs of the K value with graphs of the turbine theoretical energy.

Figure 8 shows the effects of average wind speed and Weibull parameter K on estimated power output. The instantaneous power curve for a 50 kW VAWT was used with generation limits set to cutin at a windspeed of 6.6 m/s and cutout at a windspeed of 15.65 m/s. The estimated output power is the average power that would be expected from a VAWT in one hour of operation if the wind followed a Weibull distribution.



Effect of Average Wind Speed and K-value
on Estimated Average Power from a 50 kW VAWT

Figure 8

9.7 Equipment Failures, Errors and Error Correction

The reader should be familar with previous monthly site reports prepared by T E S Limited during this program.

These reports discuss equipment failure, operator error and the methods of correction that were applied to these errors. Any analysis of the results reported here should include a familiarization with the equipment and instrumentation at each site as well as errors and corrections in the data.

Errors in the data recorded are not noted in this report except in cases where the data were seriously compromised or where significant amounts of data were missing. These notes are indicated on the Site Performance Summary Sheets with asterisks. For each asterisk, a brief description of the source of error, where known, is included as a footnote.

During the period covered by this report, a number of sites were shut down due either to equipment failure, as in the case of a failed anemometer, or for periodic maintenance, as in the case of a turbine generator. The lack of data during this down time meant that various performance figures could not be calculated for the site.

Also, some wind prospecting sites supplied single data sheets representing data collected over a time period as long as 3 months. with no previous information concerning these sites, it was decided not to split the data into arbitrary monthly segments as this could misrepresent the actual wind distribution at the site.

Footnotes for each of the Site Performance Summary Data Sheets appearing in the appendix of this report details these extraordinary conditions where they occur.

9.8 The Effects of Temperature

The density of the working fluid of turbo machinery must be included in any calculations of power or energy. Two such calculations are reported here, the Betz limit and the theoretical energy. In the case of Vertical Axis Wind Turbines, the working fluid is air, where the density is dependent on pressure, temperature and humidity.

For the Betz limit calculation, temperature compensation was applied. For each monthly report, the average monthly temperature was used based on data from the closest AES station. Pressure was assumed constant at 101.325 kPa (14.7 psi). Humidity was ignored.

Any other treatment of the air density would have been very difficult because of a lack of local data.

Turbine theoretical energy calculations summarized in reports previous to the 1983 annual report did not compensate for this effect of varying local air density. Data for each Vertical Axis Wind Turbine have been recalculated to include compensation for temperature and density effects from the initial start-up date of the turbine.

In deriving the air density compensation factors for each site, it was assumed that the DAF-Indal turbine power output curve was calibrated for standard conditions, i.e. at sea level.

$\rho = 1.225\ \text{kg/m}^3$
$P = 101.3\ \text{kPa}$
$T = 288.15^{\circ}\text{K}$

where ρ = air density
P = atmospheric pressure
T = ambient temperature

Since turbine output power is directly related to air density the calculated output energy can be adjusted to compensate for air density changes by the following factor:

$$\text{Compensated Energy Output} = \text{Calculated Energy Output} \times f_{comp}$$

where $$f_{comp} = \frac{P_{site}}{P} \times \frac{T}{T_{site}}$$

P_{site} is the site standard atmospheric air pressure as determined by altitude

and T_{site} is the site temperature as averaged over the data collection period. AES Temperature normals at locations closest to the wind test site are used to obtain this temperature value.

Table 2 listing the US Standard Atmosphere is used to approximate the standard air pressure at the altitude of the wind test sites in this test program.

Table 2

U.S. STANDARD ATMOSPHERE—METRIC UNITS

Altitude		*Temperature, t*		*Pressure, P*		*Density, ρ, kg/m³*	*Gravity, g, m/s²*	*Molecular weight, M*	*Velocity of sound, V_s, m/s*	*Viscosity, μ, kg/m·s × 10^5*	*Conductivity, k, kcal × 10^5 m·s·K*
Geometric, Z, m	*Geopotential, H, m*	*deg C*	*K*	*mbar*	*mm Hg*						
0	0	15.00	288.15	1 013.3	760.	1.225	980.7	28.96	340.3	1.789	.605 3
200	200	13.70	286.85	989.5	742.	1.202	980.6	28.96	339.5	1.783	.602 9
400	400	12.40	285.55	966.1	724.	1.179	980.5	28.96	338.8	1.777	.600 4
600	600	11.10	284.25	943.2	707.	1.156	980.5	28.96	338.0	1.771	.598 0
800	800	9.80	282.95	920.8	691.	1.134	980.4	28.96	337.2	1.764	.595 5
1 000	1 000	8.50	281.65	898.8	674.	1.112	980.4	28.96	336.4	1.758	.593 1
1 200	1 200	7.20	280.35	877.2	658.	1.090	980.3	28.96	335.7	1.752	.590 6
1 400	1 400	5.90	279.05	856.0	642.	1.069	980.2	28.96	334.9	1.745	.588 1
1 600	1 600	4.60	277.75	835.3	627.	1.048	980.2	28.96	334.1	1.739	.585 7
1 800	1 799	3.30	276.45	814.9	611.	1.027	980.1	28.96	333.3	1.732	.583 2
2 000	1 999	2.00	275.15	795.0	596.	1.007	980.0	28.96	332.5	1.726	.580 7
2 200	2 199	0.70	273.86	775.5	582.	0.987	980.0	28.96	331.7	1.720	.578 4
2 400	2 399	−0.59	272.56	756.3	567.	0.967	979.9	28.96	331.0	1.713	.575 9
2 600	2 599	−1.89	271.26	737.6	553.	0.947	979.9	28.96	330.2	1.707	.573 3
2 800	2 799	−3.19	269.96	719.2	539.	0.928	979.8	28.96	329.4	1.700	.570 8
3 000	2 999	−4.49	268.66	701.2	526.	0.909	979.7	28.96	328.6	1.694	.568 3
3 200	3 198	−5.79	267.36	683.6	513.	0.891	979.7	28.96	327.8	1.687	.565 8
3 400	3 398	−7.09	266.06	666.3	500.	0.872	979.6	28.96	327.0	1.681	.563 4
3 600	3 598	−8.39	264.76	649.4	487.	0.854	979.6	28.96	326.2	1.674	.560 9
3 800	3 798	−9.69	263.47	632.8	475.	0.837	979.5	28.96	325.4	1.668	.558 4
4 000	3 997	−10.98	262.17	616.6	462.	0.819	979.4	28.96	324.6	1.661	.555 9
4 200	4 197	−12.3	260.87	600.7	451.	0.802	979.4	28.96	323.8	1.655	.553 4
4 400	4 397	−13.6	259.57	585.2	439.	0.785	979.3	28.96	323.0	1.648	.550 8
4 600	4 597	−14.9	258.27	570.0	428.	0.769	979.3	28.96	322.2	1.642	.548 3
4 800	4 796	−16.2	256.97	555.1	416.	0.752	979.2	28.96	321.4	1.635	.545 8
5 000	4 996	−17.5	255.68	540.5	405.	0.736	979.1	28.96	320.5	1.628	.543 3
5 200	5 196	−18.8	254.38	526.2	395.	0.721	979.1	28.96	319.7	1.622	.540 8
5 400	5 395	−20.1	253.08	512.3	384.	0.705	979.0	28.96	318.9	1.615	.538 3
5 600	5 595	−21.4	251.78	498.6	374.	0.690	978.9	28.96	318.1	1.608	.535 7
5 800	5 795	−22.7	250.48	485.2	364.	0.675	978.9	28.96	317.3	1.602	.533 2

9.9 Cutin and Cutout Wind Speeds

For the purpose of this report, a cutin wind speed of 6.6 m/s (15 mph) and a cutout wind speed of 15.65 m/s (35 mph) was used unless where specified. These parameters affect only the estimated output energy and do not reflect the operating parameters of the control system at any of the turbine sites.

These parameters are used to calculate theoretical energy. They are the same for each prospecting site to facilitate comparison. In addition, the estimated output energy was calculated for a cutout wind speed of 17.88 m/s (40 mph). This information is displayed on the graphs of turbine theoretical energy but is not listed in the Sites' Performance Summary Data Sheet.

9.10 Standard Deviations of Monthly Average Wind Speed and Monthly Weibull Parameter K

Tables 3 and 4 are presented to assist in evaluating fluctuations in the monthly average wind speeds and K-value. These tables may be used in conjunction with the graphs of average wind speed and K-value. The mean of the monthly average wind speeds V_{av} for each site is given with its standard deviation. The mean of the monthly K-value (K_{av}) is also listed by site with its standard deviation.

Table 5 is included to show V_a and K_a values for each site over a period of time corresponding as closely as data would permit to a calendar year.

It should be emphasized that the averages and K-values of Tables 3 and 4 are not the same as those of Table 5, although these numbers were computed from the same data over the same time period. The mean of the monthly average wind speeds may not be the same as the average wind speed for the same period.

Similarly, by definition, the mean of the monthly K-values is not the same as the K-value for the entire time period.

10. RESULTS

Tables 3, 4 and 5 summarize the average yearly wind speed and Weibull K values described in previous sections of the report for each of the sites monitored during the calendar year 1985 and for those sites monitored during previous years of this program.

Detailed performance data for 1985, for each site providing data in 1985, including plots of frequency of occurrence vs. windspeed, and probability vs. windspeed are included in the sites' appendix.

Table 3

Mean of average monthly wind speeds (V_{av} m/sec)

Site Name	Period	Mean Wind Speed V_{av} m/sec	Std. Dev. (V_{av}) m/sec	AES Wind Speed m/sec
EAST COAST				
St Anne University	1986	6.02	0.973	4.95
St Anthony	1986	8.02	1.09	5.66
CENTRAL CANADA				
Churchill	1982	6.48	1.118	6.6
	1983	6.42	1.029	6.6
	1984	6.65	0.940	6.3
	1985	6.10	0.6099	6.3
	1986	6.90	0.718	6.3
Swift Current	1981	6.60	0.625	6.7
	1982	6.69	0.862	6.7
	1983	6.40	0.548	6.4
	1984	6.54	0.910	6.4
	1985	7.10	0.560	6.4
	1986	6.63	0.842	6.4
WEST COAST				
Christopher Point (Middle)	1981	5.35	1.250	4.9
	1982	5.55	1.610	4.9
	1983	5.31	1.458	4.9
	1984	6.28	1.428	4.9
	1985	5.55	1.204	4.9
	1986	5.30	1.088	4.9
Rattlesnake Hill	1986	3.03	0.920	2.3
NORTHERN CANADA				
Cambridge Bay	1984	6.0	0.648	6.1
	1985	6.0	0.40	6.1
Rankin Inlet	1984	8.2	0.8	6.19
	1985	7.8	1.318	6.21
	1986	6.4	1.663	6.21

Table 4

Mean of monthly K value (K_{av})

Site Name	Period	Mean K-Value K_{av}	Std. Dev. (K_{av})
EAST COAST			
St Anne University	1986	1.92	0.117
St Anthony	1986	2.18	0.042
CENTRAL CANADA			
Churchill	1982	2.14	0.387
	1983	2.18	0.327
	1984	2.17	0.237
	1985	2.16	0.350
	1986	2.15	0.274
Swift Current	1981	2.11	0.304
	1982	2.17	0.184
	1983	2.03	0.255
	1984	1.95	0.207
	1985	2.09	0.278
	1986	2.02	0.216
WEST COAST			
Christopher Point (Middle)	1981	1.69	0.499
	1982	1.64	0.552
	1983	1.60	0.413
	1984	1.76	0.488
	1985	1.62	0.373
	1986	1.58	0.469
Rattlesnake Hill	1986	1.83	0.230
NORTHERN CANADA			
Cambridge Bay	1984	2.05	0.391
	1985	2.40	0.100
Rankin Inlet	1984	2.62	0.57
	1985	1.95	0.342
	1986	1.90	0.652

Table 5

Average wind speed V_a and K parameter K_a for period of report

Site Name	Period	Calculated Wind Speed V_a m/sec	Calculated K-Value K_a
EAST COAST			
St Anne University	1986	5.56	1.69
St Anthony	1986	8.10	2.0
CENTRAL CANADA			
Churchill	1982	6.53	1.86
	1983	6.43	1.87
	1984	6.68	1.92
	1985	6.10	1.83
	1986	6.90	1.93
Swift Current	1981	6.50	2.03
	1982	6.79	1.97
	1983	6.41	1.99
	1984	6.50	1.84
	1985	7.07	1.95
	1986	6.70	1.96
WEST COAST			
Christopher Point (Middle)	1981	5.30	1.52
	1982	5.79	1.55
	1983	5.54	1.44
	1984	5.75	1.49
	1985	5.52	1.52
	1986	5.40	1.44
Rattlesnake Hill	1986	3.0	1.71
NORTHERN CANADA			
Cambridge Bay	1984	5.84	1.75
	1985	5.95	2.23
Rankin Inlet	1984	7.72	2.21
	1985	7.72	1.71
	1986	6.70	1.63

APPENDIX INDEX

APPENDIX INDEX

Site Name	Type	Instrumentation	Appendix
Christopher Point	(P/G)	WECS	A
Churchill	(P/G)	WECS	B
Rankin Inlet	(P)	WHR/DAF	C
Rattlesnake Hill	(P)	WHR/DAF	D
St Anthony	(P)	WHR/DAF	E
Sainte Anne University	(P)	WHR/DAF	F
Swift Current	(P/G)	WECS	G

P - Wind prospecting site. No actual performance data.

P/G - Wind prospecting and generating site. Both actual and estimated data.

WHR/DAF - Daf Indal Wind Histogram Recorder

WECS - Wind Energy Conversion System

Appendix A

Christopher Point

AIR DENSITY COMPENSATION FACTORS
BASED ON
A.E.S. NORMALS AT THE CLOSEST A.E.S. STATION

SITE: Christopher Point

ALTITUDE: 69m CLOSEST A.E.S. STATION: Victoria

STD AIR PRESSURE: 100.51Kpa

	AVERAGE MONTHLY A.E.S. TEMPERATURE T_{avg} °K	COMPENSATION FACTOR f_{comp} $f_{Comp} = \frac{288.15}{T_{avg}} \times \frac{\text{Std Air Pressure}}{101.33}$
JANUARY	279.1	1.024
FEBRUARY	281.2	1.016
MARCH	282.6	1.011
APRIL	285.6	1.001
MAY	288.7	0.990
JUNE	290.7	0.983
JULY	292.7	0.976
AUGUST	292.4	0.977
SEPTEMBER	291.0	0.982
OCTOBER	286.7	0.997
NOVEMBER	282.3	1.012
DECEMBER	280.2	1.020

Notes: Compensated Energy Output = Estimated Energy Output x f_{comp}

A.E.S. data obtained from Canadian Climate Normals

Temperature 1951 - 1980 UDC: 551.582(71)

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHRISTOPHER POINT MIDDLE

CUT IN WIND SPEED 6.60 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1981				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE						ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME	ACTUAL GEN. % OF EST. GEN. TIME	DOWN TIME % OF TOTAL TIME PERIOD	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD HR	AVERAGE WIND SPEED M/S	K	AVAIL. WIND ENERGY BETZ LIMIT KW-HR.	EST. GEN. TIME HR	EST. OUTPUT ENERGY KW-HR	DOWN TIME HR	STOP TIME HR	IDLE TIME HR	ACTUAL GEN. TIME HR	ACTUAL INPUT ENERGY KW-HR	ACTUAL OUTPUT ENERGY KW-HR	KW-HR	%	%	%	%	KW-HR
JAN.																		
FEB.																		
MAR.	671	4.5	1.68	8032	148	2058.4	11.7	507.6	26.7	125	36.0	1993		24.8	96.8	84.3	1.7	2131.2
APR.	817	5.9	1.39	24419	274	5280.3	331.7	308.1	16.2	161	47.0	3347		13.7	63.4	58.9	40.6	6370.4
MAY	695	5.7	1.80	14746	260	3854.1	123.1	352.4	18.5	201	82.8	2521		17.1	65.4	77.5	17.7	4202.6
JUNE	648	5.6	2.01	11611	249	3362.8	293.6	207.5	10.9	136	38.4	1790		15.4	53.2	54.6	45.3	3409.0
JULY	668	7.4	2.55	19492	406	5930.2	24.3	221.1	11.6	411	73.2	5968		30.6	100.6	101.0	3.6	6081.5
AUG.	817	6.6	2.28	20048	433	6041.8	7.7	333.7	17.6	458	68.4	6482		32.3	107.3	106.0	0.9	6174.6
SEPT.	688	5.0	1.71	10876	215	2727.0	0.0	438.9	23.1	226	56.0	2872		26.0	105.3	104.6	0.0	2919.5
OCT.	842	3.1	1.16	4534	75	865.4	4.3	333.1	38.6	66	42.0	696		15.4	80.4	88.7	0.5	944.2
NOV. *1	672	4.0	0.97	7640	88	1244.8	258.2	375.1	19.7	19	18.0	288		3.7	23.1	21.7	38.4	1606.1
DEC. *2	1168	5.2	1.30	24403	315	5610.0	749.9	332.6	17.5	68	66.0	1069		4.4	19.1	21.8	64.2	6429.1
SUM	7686	5.3	1.52	145801	2463	36974.8	1804.5	3410.1	200.4	1871	5278.0	27026		18.5	73.1	75.9	23.4	40268.2

NOTES: Explanation on following page.

NOTES ON CHRISTOPHER POINT (MIDDLE) 1981

*1 Many corrections made to the data.

*2 Includes 15 days of January 1982.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHRISTOPHER POINT MIDDLE

CUT IN WIND SPEED 6.60 m/s
CUT OUT WIND SPEED 15.65 m/s *6

YEAR: 1982				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD HR	AVERAGE WIND SPEED M/S	K	AVAIL. WIND ENERGY BETZ LIMIT KW-HR	EST. GEN. TIME HR	EST. OUTPUT ENERGY KW-HR	DOWN TIME HR	STOP TIME HR	IDLE TIME HR	ACTUAL GEN. TIME HR	ACTUAL INPUT ENERGY KW-HR	ACTUAL OUTPUT ENERGY KW-HR	ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA KW-HR	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY %	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME %	ACTUAL GEN. % OF EST. GEN. TIME %	DOWN TIME % OF TOTAL TIME PERIOD %	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED KW-HR
JAN. *1	648.0	3.5	1.82	-	-	-	393.7	231.7	12.1	10.4	24	72		-	-	-	60.8	
FEB. *2	337.6	4.6	1.07	5537	61.0	928.4	10.5	258.4	13.6	55.1	12	816		14.7	87.9	90.3	3.1	1230.0
MAR. *3	671.0	4.4	0.97	10872	107.6	1405.3	179.3	374.5	19.7	97.5	48	1164	932.5	10.7	83.7	91.1	26.7	2172.6
APR.	669.2	5.1	1.50	11444	190.6	2773.4	269.7	243.5	12.8	143.2	34	1996	2114.7	17.4	72.0	75.1	40.3	2987.1
MAY *4	792.1	7.9	2.25	32916	474.9	8676.5	538.4	206.3	12.1	35.3	66	583	415.5	1.8	6.7	7.4	66.0	9496.0
JUNE	576.7	7.4	2.29	18896	353.5	5335.0	198.4	227.9	12.0	138.4	72	3111	2277.0	16.5	58.3	39.7	34.4	5416.4
JULY	999.9	8.1	2.28	43727	648.8	12045.0	113.3	323.1	14.9	548.6	52	8346	7839.7	19.1	69.3	84.6	11.8	12241.4
AUG. *5	550.8	7.1	2.06	18202	293.1	5206.2	304.8	233.7	12.3	0	0	0	N/A	0	0	0	55.3	5263.8
SEPT.	1150.8	4.8	1.75	14146	293.0	3724.4	203.4	851.9	44.8	50.7	9.6	382	245.6	2.7	10.3	17.3	17.7	3728.3
OCT.	817.0	4.5	1.12	9571	130.5	2190.4	433.9	317.4	15.4	50.3	12	764	716.6	8.0	34.9	38.5	54.8	2307.0
NOV.	527.9	4.1	1.88	2956	59.2	439.4	25.0	451.3	24.0	27.6	58.8	270	244.8	9.1	61.5	46.6	4.5	439.4
DEC.	335.6	5.1	0.79	7943	54.0	1404.0	4.2	264.9	13.9	52.6	13.2	1176	1181.1	14.8	83.7	97.4	1.25	1421.9
SUM	8126.6	5.55	1.55	176210	2666.2	44128.0	2674.6	3984.6	207.7	1209.7	401.6	18680	15967.5	10.6	42.2	45.0	32.91	46653.9

NOTES: Explanation on following page.

NOTES ON CHRISTOPHER POINT (MIDDLE) 1982

*1 The period of this data is from January 15 to February 11, 1982. However there was no histogram data recorded between 15 January and 2 February. As a result estimated performance calculations were not done. The average wind speed and K values are for a 9 day period only.

*2 Covers the period from February 11 to February 25, 1982.

*3 "Generate Only" histogram recorder installed.

*4 Cut-out wind speed raised from 15.65 m/s (35 mph) to 17.8 m/s (40 mph) on May 25 1982.

*5 Turbine not operating.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHRISTOPHER POINT (Middle)

CUT IN WIND SPEED 6.60 m/s
CUT OUT WIND SPEED 17.9 m/s

YEAR: 1983				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD HR	AVERAGE WIND SPEED M/S	K	AVAIL. WIND ENERGY BETZ LIMIT KW-HR.	EST. GEN. TIME HR	EST. OUTPUT ENERGY KW-HR	DOWN TIME HR	STOP TIME HR	IDLE TIME HR	ACTUAL GEN. TIME HR	ACTUAL INPUT ENERGY KW-HR	ACTUAL OUTPUT ENERGY KW-HR	ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA KW-HR	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY %	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME %	ACTUAL GEN. % OF EST. GEN. TIME %	DOWN TIME % OF TOTAL TIME PERIOD %	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED KW-HR
JAN.	983.6	5.4	0.93	27709	218.3	4326.9	94.0	711.2	37.4	141.0	34.8	3612	3579.5	13.0	83.5	64.6	9.6	5294.8
FEB.	1058.6	4.5	1.3	11374	192.1	2601.3	913.1	112.6	5.9	27.0	60.0	252	340.1	22.2	9.7	14.1	84.1	2667.6
MAR.	313.0	4.5	1.83	2604	56.5	539.7	313.0	0.0	0.0	0.0	12.0	0	21.4	0.0	0.0	0.0	100.0	540.0
APR. *1	670.3	5.3	1.60	11686	214.7	3286.1	50.4	101.6	5.3	59.4	12.0	1014	949.7	8.7	30.9	27.7	7.5	3323.7
MAY *2	1008.7	6.2	1.56	25621	404.4	6550.2	0.0	493.0	93.0	422.0	60.0	6154	5701.9	24.0	94.0	104.5	0.0	6670.3
JUNE	672.9	6.8	2.08	18264	346.7	5429.8	0.0	229.9	80.0	363.0	42.0	4356.0	5082.2	23.9	80.2	54.0	0.0	5437.4
JULY	669.8	6.5	1.93	17297	319.3	5005.8	0.0	313.4	16.5	339.4	42.0	5844.0	4666.8	33.8	116.7	106.3	0.0	5055.7
AUG.	667.3	7.0	2.05	19960	355.7	5809.4	268.4	184.0	9.7	205.2	32.0	3384.0	2958.6	17.0	58.3	57.7	40.2	5927.5
SEPT.	503.7	5.1	1.75	6895	141.2	1804.5	0.0	338.2	17.8	141.2	24.0	1920.0	1716.9	27.9	106.3	100.0	0.0	1808.5
OCT. *3	1118.6	4.1	1.22	11990	210.8	2813.0	0.0	915.1	41.2	218.0	60.0	3036.0	2419.5	25.3	107.9	103.4	0.0	2895.2
NOV. *4																		
DEC. *4																		
SUM	7666.5	5.3	1.44	153400	2140.4	43816.7	2092	3399	306.8	1916.2	378.8	29572.0	27436.6	19.3	67.5	89.5	27.3	39620.7

NOTES: Explanation on following page.

NOTES ON CHRISTOPHER POINT (MIDDLE) 1983

*1 The available clock recorded for only 4.6 hours. This problem is currently under investigation.

*2 Data recorded for this period was missing counts. Bins 3, 4, 5 and 6 were altered to increase the recorded time to that of the calendar time for this period.

*3 Total recorded time is 2.4 days less than that of the calendar time.

*4 Data included in the results of February 1984.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHRISTOPHER POINT (MIDDLE)

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 17.9 m/s

YEAR: 1984				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD	③ AVERAGE WIND SPEED	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT	⑥ EST. GEN. TIME	⑦ EST. OUTPUT ENERGY	⑧ DOWN TIME	⑨ STOP TIME	⑩ IDLE TIME	⑪ ACTUAL GEN. TIME	⑫ ACTUAL INPUT ENERGY	⑬ ACTUAL OUTPUT ENERGY	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME)	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED
	h	m/s		kWh	h	kWh	h	h	h	h	kWh	kWh	kWh	%	%	%	%	kWh
JAN.*1																		
FEB.*2	2519.3	5.2	1.24	49607	385.6	11028.3	0.0	2093.3	39.3	386.4	61.2	7646.4	7286.5	15.4	69.3	59.0	0.0	11729.0
MAR.	840.4	4.6	1.47	10771	192.9	2745.3	72	606.5	18.5	143.4	34.8	2853.6	2456.9	26.5	103.9	74.3	8.6	2940.6
APR.	684.4	5.2	1.35	12029	192.2	2842.3	0.0	432.2	38.4	177.4	42.0	2670.0	2704.6	22.2	93.9	92.3	0.0	3018.5
MAY	885.3	5.9	1.62	19718	337.1	5361.9	1.8	500.4	39.4	343.8	60.0	5600.0	5351.9	28.4	104.4	102.0	0.2	5510.3
JUNE*7	674.7	8.1	2.47	26801	472.5	8083.6	0.0	150.5	25.5	498.7	42.0	8655.6	8107.3	32.3	107.1	105.5	0.0	8224.1
JULY	481.2	8.2	2.33	21004	324.5	6553.2	0.0	128.7	15.5	340.0	21.6	7053.0	6583.8	33.6	107.6	104.8	0.0	6635.1
AUG.	669.3	7.9	2.31	25244	440.0	7495.9	0.0	185.4	19.7	463.2	8.4	8136.0	7624.6	32.2	108.5	105.3	0.0	7682.2
SEP.*3																		
OCT.*3																		
NOV.*4	2572.1	5.1	1.28	47799	696.2	10670.3	1432.2	763.2	37.0	336.9	78.0	4298.4	*5	9.0	40.3	48.4	55.7	11456.3
DEC.*6																		
SUM.	9326.7	5.7	1.49	212973	3310.3	54780.8	1506	4881.5	233.3	2689.8	348	46813	40115.6	22.0	85.5	81.3	16.1	56996.1

NOTES: Explanation on following page.

NOTES ON CHRISTOPHER POINT (MIDDLE) 1984

*1 Data included in the results for February, 1984.

*2 Data period is from November 4, 1983 to February 13, 1984.

*3 Data included in November 1984.

*4 Data period from August 23 to December 7, 1984.

*5 No data received from "generate only" histogram recorder.

*6 Data from December 7, 1984 to December 31, 1984 included in January 1985 reporting.

*7 Data period June 7, 1984 to July 5, 1984. Recorder left in HOLD mode from May 25, 1984 to June 7, 1984. Estimated and actual performance figures are for 28 days.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHRISTOPHER POINT (MIDDLE)

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 17.9 m/s

YEAR: 1985				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN. *1	1175.7	4.3	1.32	12346	194.2	2949.9	1174.0	1.4	0.2	1.0	9.6	1.6	0.0	0.0	0.1	0.5	99.9	2991.9
FEB.	621.7	4.9	1.07	11861	137.0	2243.8	334.3	287.2	0.0	0.2	2.4	13.2	0.0	0.1	0.5	0.0	53.8	2583.2
MAR. *2	936.0						936.0	0.0	0.0	0.0	27.4	0.0				0.0	100.0	
APR. *3	840.0						0.0	399.4	21.1	419.5	44.4	7239.6					0.0	
MAY *4	694.7	6.9	1.83	22210	347.9	6146.7	0.0	290.6	33.6	370.9	30.0	6754.8	6281.5	30.4	109.9	106.6	0.0	6393.6
JUNE	682.4	7.0	1.77	23954	350.8	6477.3	0.0	281.2	25.8	375.6	42.0	6950.4	6444.5	29.0	107.3	107.9	0.0	6760.5
JULY	792.1	7.8	2.49	28594	516.0	9064.1	0.0	209.2	40.9	556.2	46.8	10210.8	9692.4	35.7	112.7	107.8	0.0	9106.3
AUG.	677.3	5.7	1.85	13528	255.8	4124.8	6.5	387.2	25.1	258.2	31.2	4183.2	3923.6	30.9	101.4	101.1	0.96	4140.8
SEP.	723.9	4.5	1.42	8928	169.0	2320.9	4.1	548.4	18.5	152.9	30.0	2262.0	2193.0	25.3	97.5	90.5	0.57	2367.2
OCT.	597.0	4.8	1.47	8648	159.6	2309.2	1.4	419.6	18.4	157.6	26.4	2336.4	2262.3	27.02	101.2	98.7	0.24	2346.3
NOV. *5	717.8	5.4	1.63	13426	219.7	3747.7	0.0	525.6	16.4	175.8	33.6	3270.0	2513.0	24.4	87.3	80.0	0.0	3771.6
DEC.	672.0	4.2	1.38	4856	94.5	873.5	0.3	657.4	2.2	12.1	6.0	237.6	232.7	4.89	27.2	12.8	0.48	873.9
SUM.	9130.6	5.52	1.52	148351	2444.5	40257.9	2456.6	4007.2	202.2	2480	329.8	43459.6	33543	29.2951	107.953	101.452	26.905	41335.3

NOTES: Explanation on following page.

NOTES ON CHRISTOPHER POINT (MIDDLE)

*1 Data period from December 8, 1984 to January 25, 1985.

*2 Histogram data lost in transit to T E S Limited. Only actual performance figures were available. Data period from February 20 to March 31, 1985.

*3 Histogram data lost in transit to T E S Limited. Only actual performance figures were available. Data period from April 1 to May 5, 1985.

*4 Data period from May 6 to June 3, 1985.

*5 The site inspector accidentally reset the "Generate Only" histogram recorder on November 25, 1985. Hence, the estimated output energy (column 14) represents the period October 27 to November 11, 1985. All other information is for the full period October 27 to November 25, 1985.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHRISTOPHER POINT (MIDDLE) COMPENSATED

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 17.9 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE						⑭	⑮	⑯	⑰	⑱	⑲
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	ACTUAL GEN. TIME % OF EST. GEN. TIME %	DOWN TIME % OF TOTAL TIME IN PERIOD %	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.	839.1	5.2	0.95	20368	165.9	2883.8	3.4	741.6	10.4	83.7	19.2	2178	2143.9	10.7	75.5	50.5	0.4	3730.6
FEB.	671.6	4.5	1.01	9773	114.5	1665.6	2.1	594.1	4.5	70.9	13.2	1575.6	1517.8	16.1	94.6	61.9	0.3	1953.9
MAR.	653.3	4.3	1.41	7380	128.0	1844.3	0	528.6	12.3	112.8	21.6	1845.6	1743.5	25.0	100.1	88.1	0	1858.2
APR.	722.3	6.0	1.59	19488	281.7	5159.9	0	394.3	29.4	298.6	42.0	5551.2	5268.4	28.5	107.6	106.0	0	5321.0
MAY	977.6	6.1	1.80	23649	427.7	6813.7	2.7	490.2	37.8	446.9	57.6	7299.6	6793.3	30.9	107.1	104.5	0.3	6930.5
JUNE	580.0	5.9	1.82	12333	240.5	3507.4	12.1	321.1	17.7	229.1	34.8	3582.0	3330.4	29.0	102.1	95.3	2.1	3542.8
JULY	933.3	7.6	2.54	29183	602.8	9235.9	0.3	295.4	9.9	627.7	62.4	9850.8	5256.1	33.8	106.7	104.1	0.0	9277.7
AUG.	642.3	6.2	2.09	14573	306.6	4300.9	0.8	324.4	0.7	316.4	37.2	4531.2	4263.7	31.1	105.4	103.2	0.1	4314.6
SEP.	696.2	5.3	1.76	11763	253.3	3356.9	0.0	435.2	0.4	260.6	40.8	3570.0	3330.9	30.3	106.3	102.9	0	3385.4
OCT.	647.7	3.4	1.83	3379	66.3	768.7	0.0	588.0	0.0	59.7	12.0	780.0	718.5	23.1	101.5	90.0	0	768.7
NOV.	696.6	4.7	1.22	11168	155.7	2717.3	0.7	545.7	0.0	150.2	27.6	2738.4	2708.0	24.5	100.8	96.5	0.1	2851.1
DEC.*1	981.7	4.3	0.97	12594	135.0	2297.0	5.5	897.4	0.0	78.8	15.6	1855.2	1837.1	14.7	80.8	58.4	0.6	2566.7
SUM.	9041.7	5.4	1.44	175651	2878.0	44551.4	27.6	5156.0	123.1	2735.4	384.0	45357.6	38911.7	25.8	101.8	95.0	0.3	46500.5

NOTES: Explanation on following page

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHRISTOPHER POINT (MIDDLE)

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 17.9 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.	839.1	5.2	0.95	20368	165.9	2816.2	3.4	741.6	10.4	83.7	19.2	2178	2093.7	10.7	77.3	50.5	0.4	3643.2
FEB.	671.6	4.5	1.01	9773	114.5	1639.4	2.1	594.1	4.5	70.9	13.2	1575.6	1493.9	16.1	96.1	61.9	0.3	1923.1
MAR.	653.3	4.3	1.41	7380	128.0	1824.2	0	528.6	12.3	112.8	21.6	1845.6	1724.5	25.0	101.2	88.1	0	1838.0
APR.	722.3	6.0	1.59	19488	281.7	5154.7	0	394.3	29.4	298.6	42.0	5551.2	5263.1	28.5	107.7	106.0	0	5315.7
MAY	977.6	6.1	1.80	23649	427.7	6882.5	2.7	490.2	37.8	446.9	57.6	7299.6	6861.9	30.9	106.1	104.5	0.3	7000.5
JUNE	580.0	5.9	1.82	12333	240.5	3568.1	12.1	321.1	17.7	229.1	34.8	3582.0	3388.0	29.0	100.4	95.3	2.1	3604.1
JULY	933.3	7.6	2.54	29183	602.8	9395.6	0.3	295.4	9.9	627.7	62.4	9850.8	5385.3	33.8	104.8	104.1	0.0	9438.1
AUG.	642.3	6.2	2.09	14573	306.6	4402.2	0.8	324.4	0.7	316.4	37.2	4531.2	4364.1	31.1	102.9	103.2	0.1	4416.2
SEP.	696.2	5.3	1.76	11763	253.3	3435.9	0.0	435.2	0.4	260.6	40.8	3570.0	3392.0	30.3	103.9	102.9	0	3465.1
OCT.	647.7	3.4	1.83	3379	66.3	771.0	0.0	588.0	0.0	59.7	12.0	780.0	720.7	23.1	101.2	90.0	0	771.0
NOV.	696.6	4.7	1.22	11168	155.7	2685.1	0.7	545.7	0.0	150.2	27.6	2738.4	2675.9	24.5	102.0	96.5	0.1	2817.3
DEC.*1	981.7	4.3	0.97	12594	135.0	2251.9	5.5	897.4	0.0	78.8	15.6	1855.2	1801.1	14.7	82.4	58.4	0.6	2516.4
SUM.	9041.7	5.4	1.44	175651	2878.0	44826.8	27.6	6156.0	123.1	2735.4	384.0	45357.6	39164.2	25.8	101.2	95.0	0.3	46748.7

NOTES: Explanation on following page.

NOTES ON CHRISTOPHER POINT 1986

*1 Data recording period November 25, 1986 to January 4, 1987.

MONTHLY AVERAGE WIND SPEED AND WEIBULL PARAMETER "K" AS CALCULATED FROM CONTINUOUSLY RUNNING WIND HISTOGRAM RECORDER

SITE NAME: CHRISTOPHER POINT (MIDDLE)

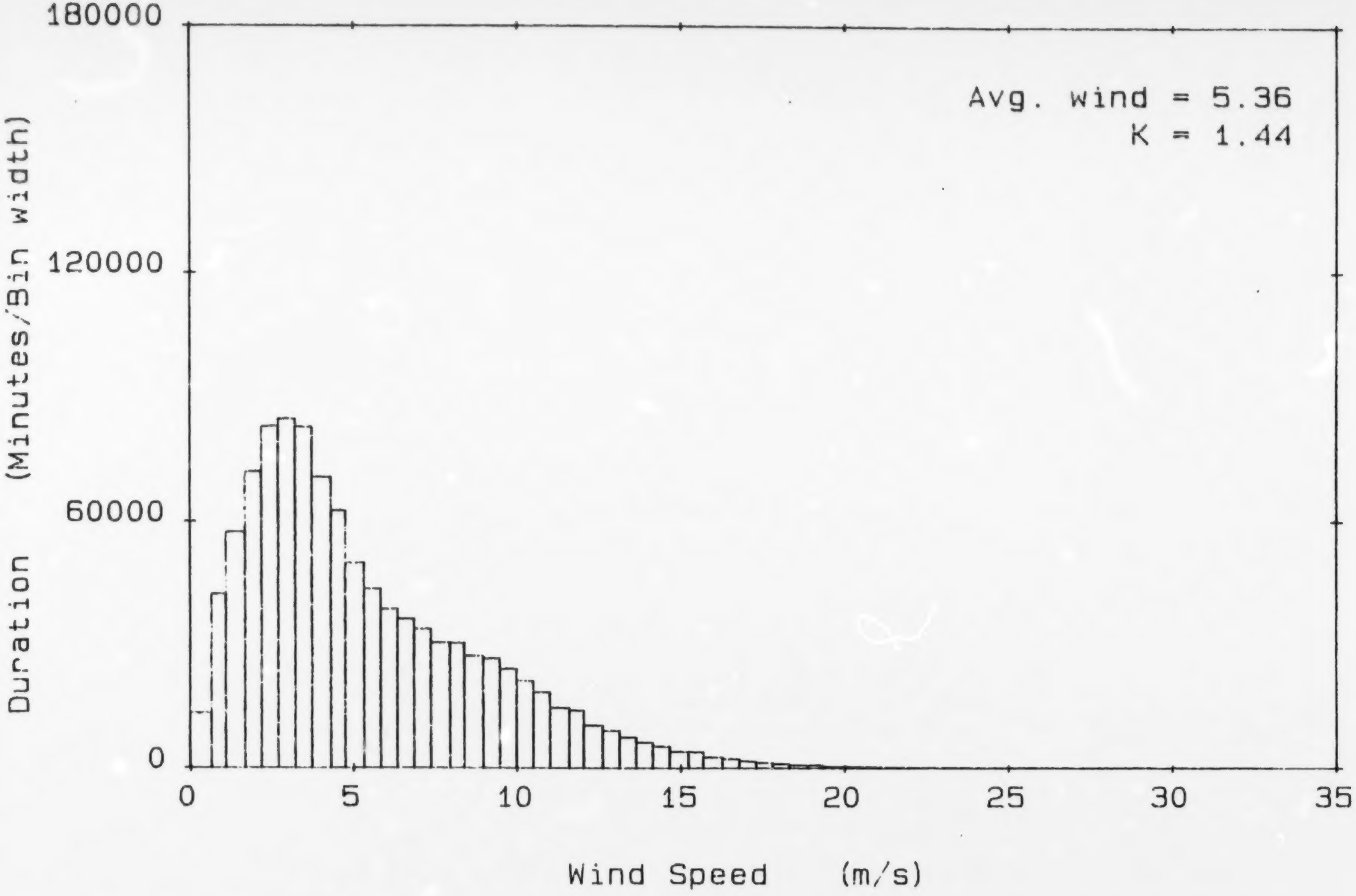
YEAR: 1986

APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January	839.1	5.2	0.95	0.253
February	671.6	4.5	1.01	0.268
March	653.3	4.3	1.41	0.121
April	722.3	6.0	1.59	0.051
May	977.6	6.1	1.80	0.032
June	580.0	5.9	1.82	0.033
July	933.3	7.6	2.54	0.005
August	642.3	6.2	2.09	0.018
September	696.2	5.3	1.76	0.044
October	647.7	3.4	1.83	0.077
November	696.6	4.7	1.22	0.155
December*1	981.7	4.3	0.97	0.309
YEAR	9,041.7	5.4	1.44	0.084

Notes: *1 Data reported for period November 25, 1986 to January 4, 1987.

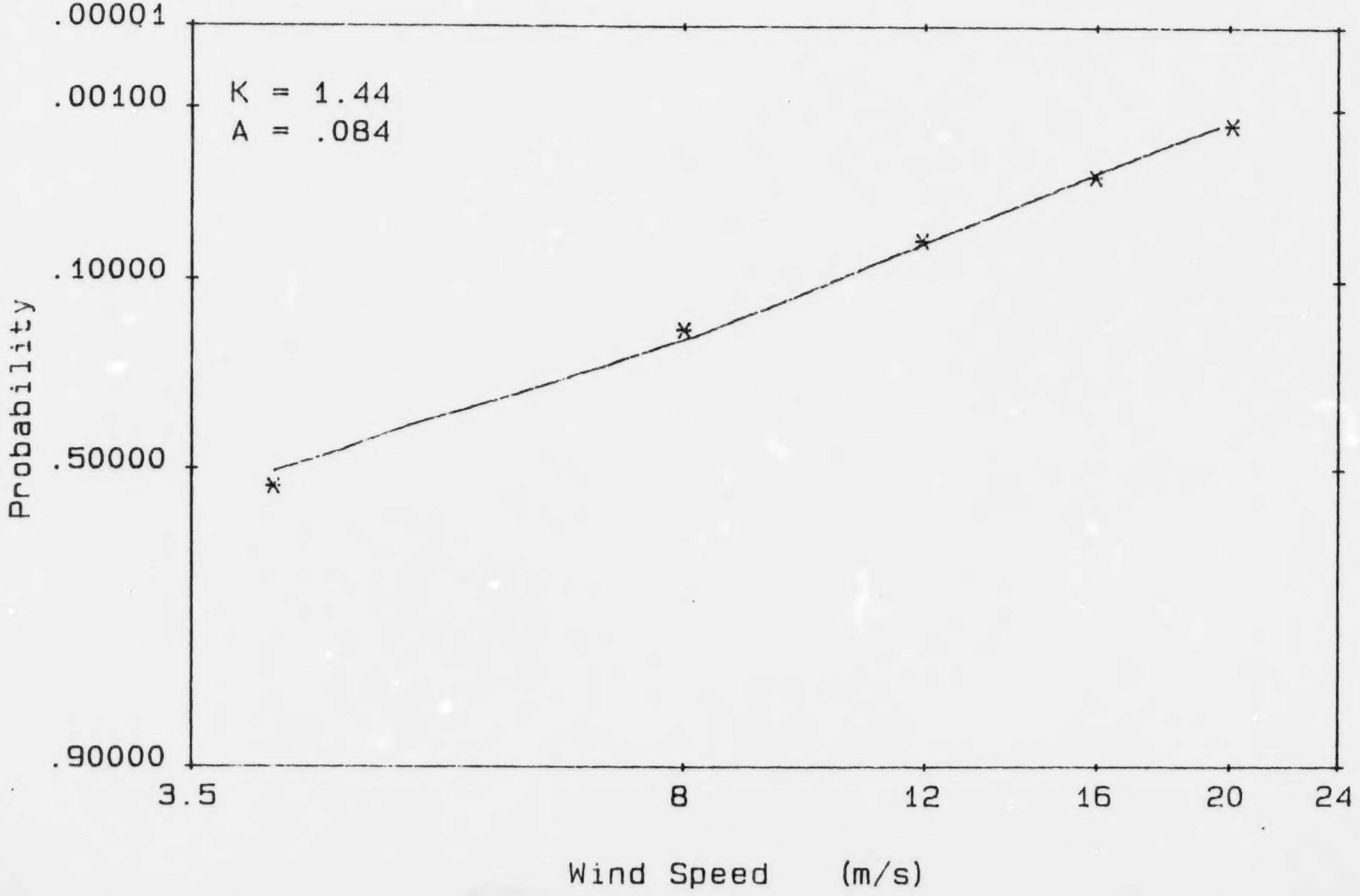
CHRISTOPHER POINT (MIDDLE)

December 24 1985 to January 4 1987



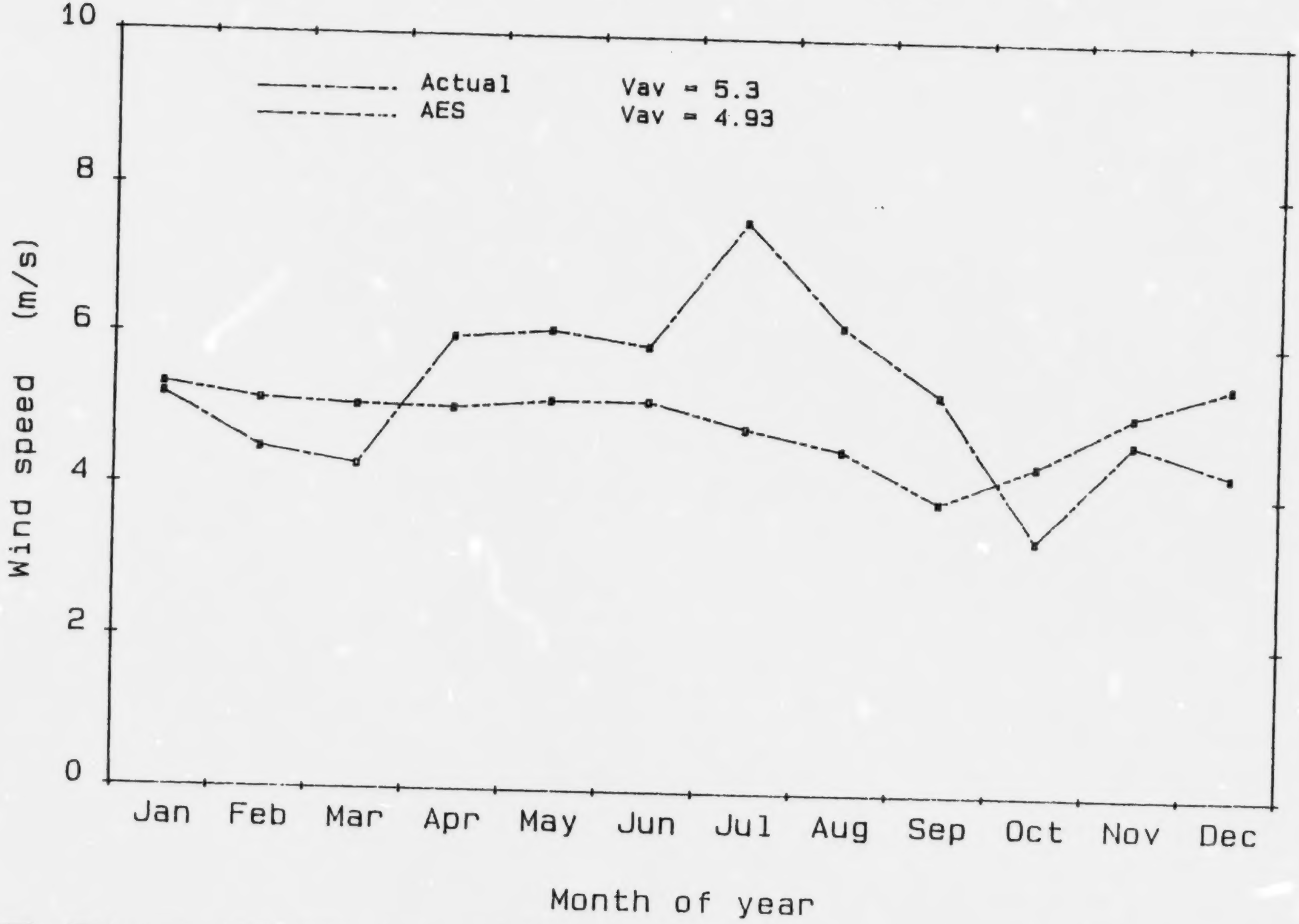
CHRISTOPHER POINT (MIDDLE)

December 24 1985 to January 4 1987



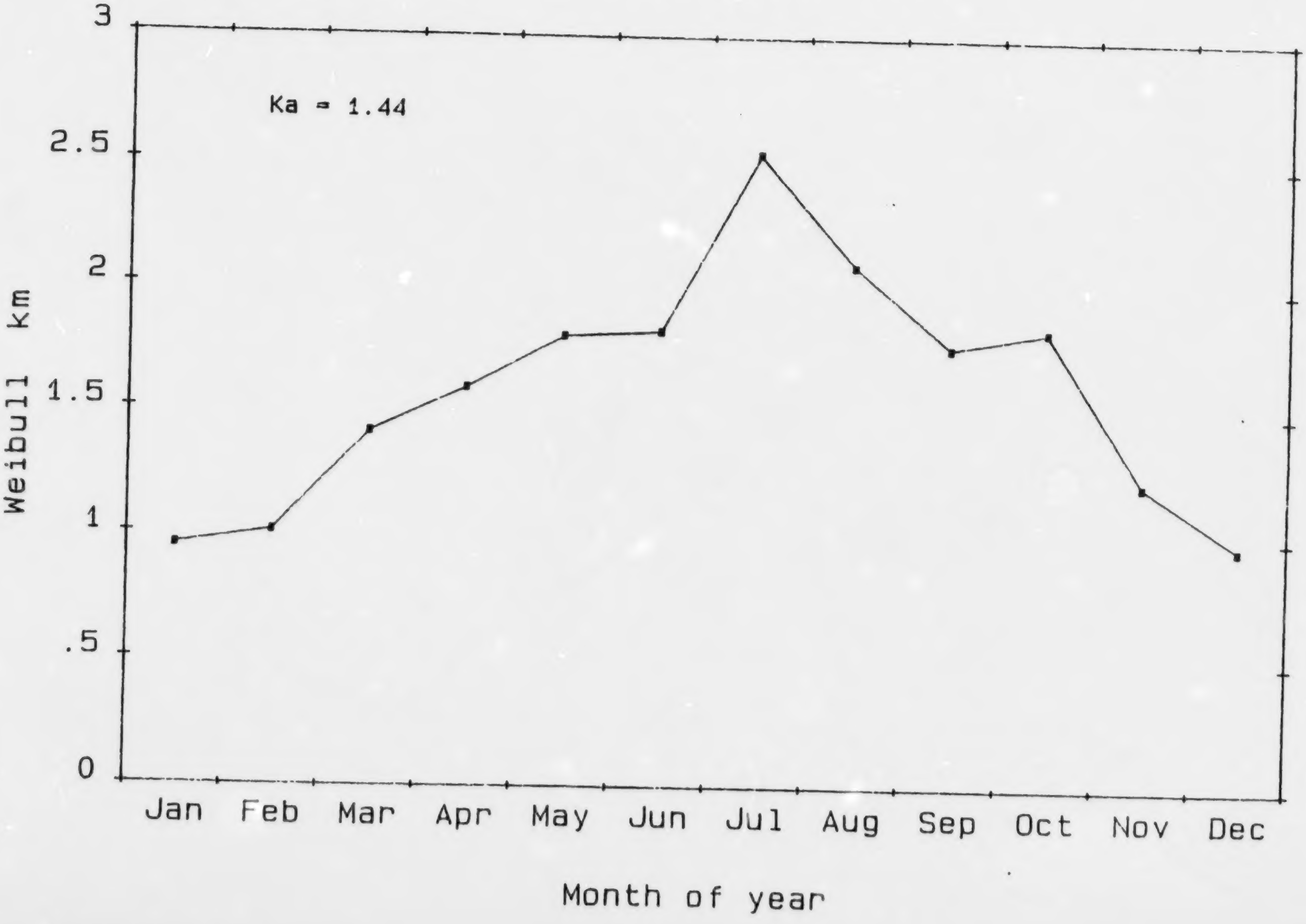
COMPARISON OF AVERAGE WIND SPEEDS

CHRISTOPHER POINT 1986



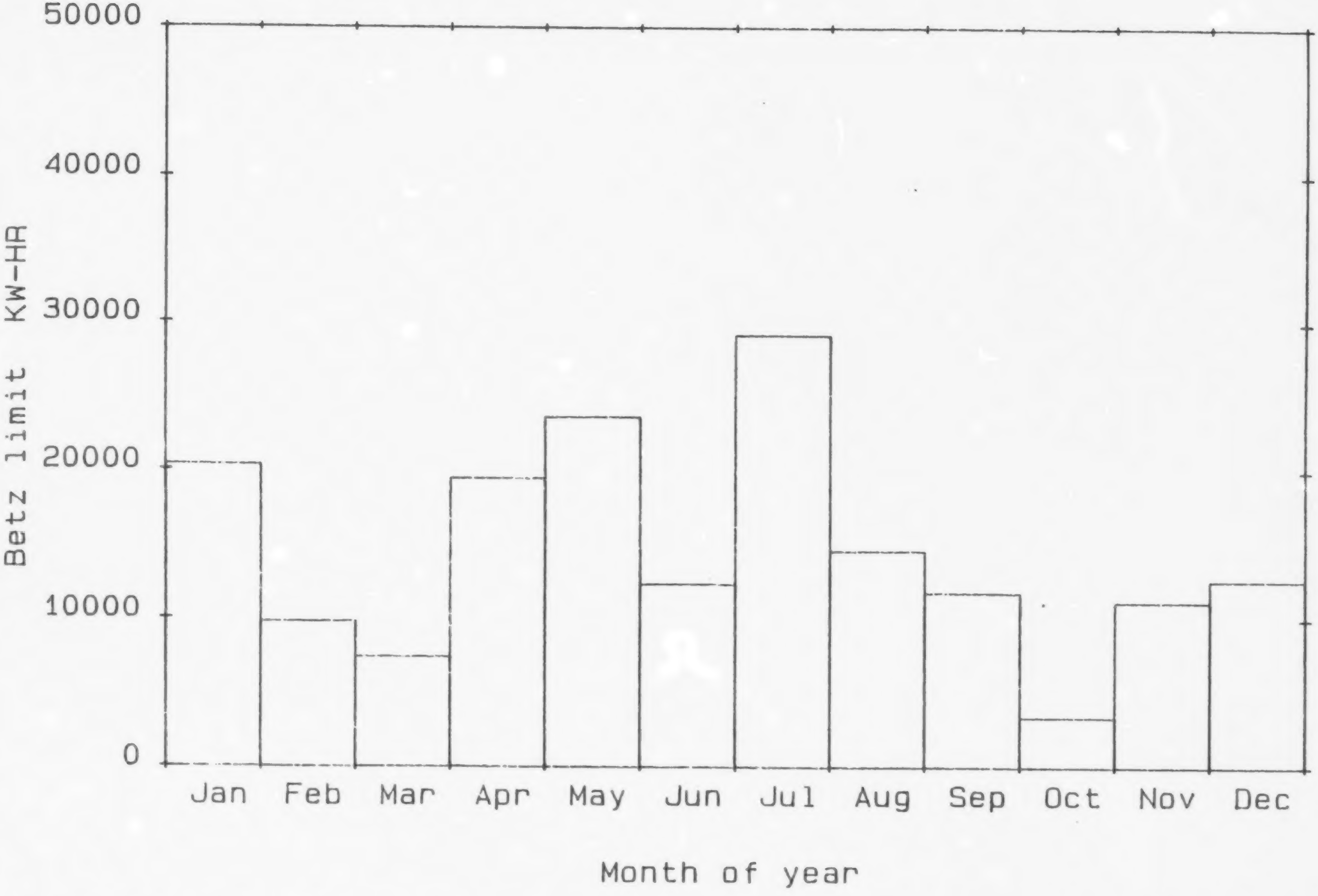
WEIBULL PARAMETER km VS month

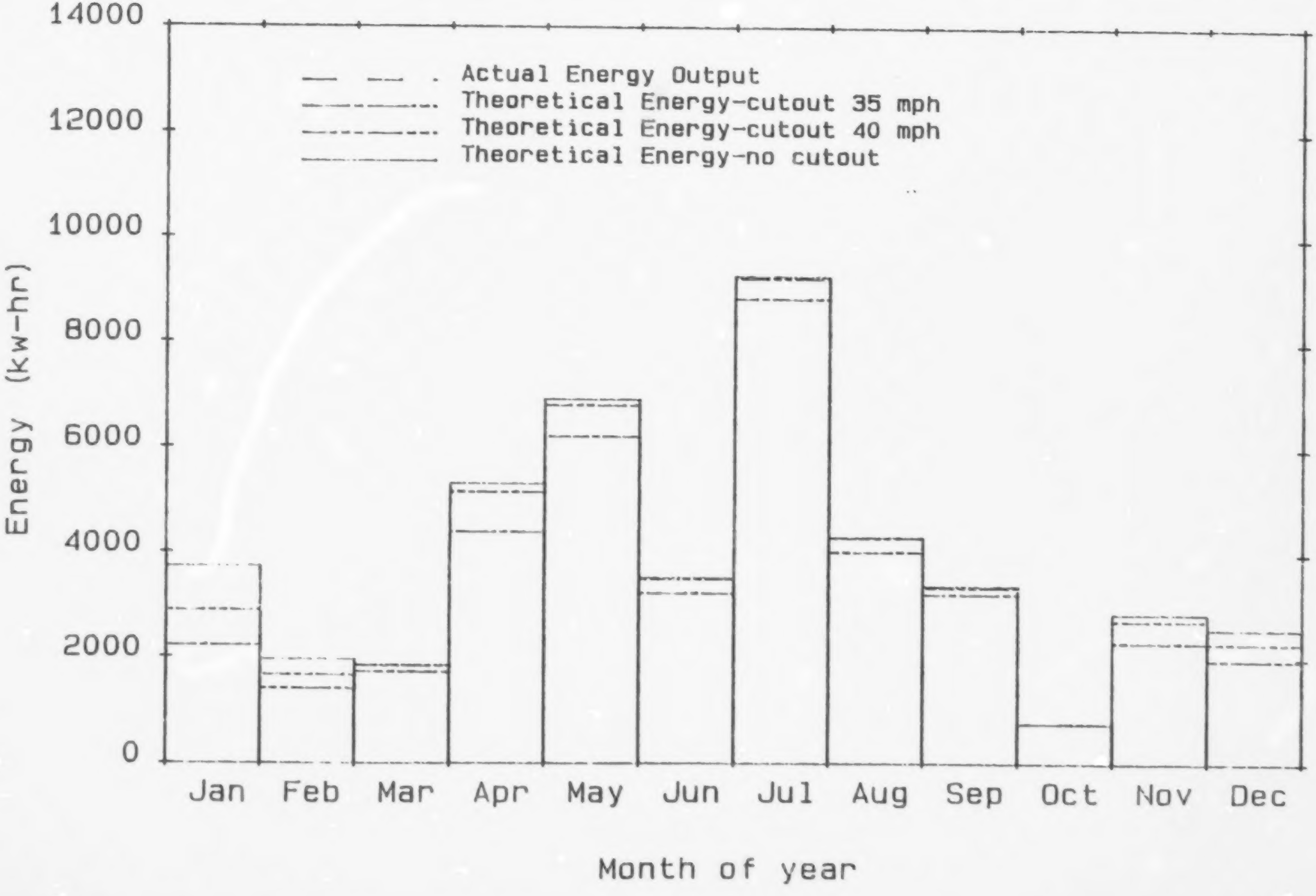
CHRISTOPHER POINT 1986



BETZ LIMIT KW-HR

CHRISTOPHER POINT 1986





TURBINE THEORETICAL ENERGY KW-HR

CHRISTOPHER POINT 1986

VAWT SYSTEM NOTES: CHRISTOPHER POINT

Jan, 1981	One of the guy tension cards found to have been damaged and not replaced immediately. Middle Wind Histogram Recorder (WHR) not operating.
Feb, 1981	Oil leak noticed and cause not apparent. Cut-in raised from 10 to 14 mph (4.47 to 6.26 m/s) and cut-out raised from 30 to 35 mph (13.41 to 15.56 m/s). Generate only WHR found to be inoperative near end of month.
Mar, 1981	During the month a phase/voltage trip occured. It was suspected that this resulted from a power failure on the main power grid. The VAWT was shut down during maintenance to the grid. The generate-only WHR was repaired by replacing two printed circuit cards.
Apr, 1981	VAWT down for repairs of new PT's, wiring, change of capacitors, etc. Trailer meters not functioning properly.
May, 1981	It was found that two of the trip indicators on the trip indicator board were not connected. The tension meter was found to be inoperative and it was suggested that both this meter and a faulty thermal relay be replaced. Oil leaks were found near the brake shoes, but this was not considered a serious problem. The generate-only WHR which had been repaired recently, failed again.

June, 1981	The tension meter was still reading incorrectly and a fuse on the pump motor had blown. This fuse was replaced, however, the cause for the failure was not found. As a result of an oil leak an oily scale had built up on the shoes, but was considered not serious. Guy tension card tripped and needed replacement. This month's down-time is due to waiting for parts.
July, 1981	The lubrication oil was changed this month. The leak still persisted. Turbine shut down on 25-26 July 1981 to investigate oil disappearance.
Aug, 1981	The guy tension meter was still not operating correctly. The circuit cards for the guy tension were replaced, however this did not make any difference. It was suspected that the meter itself was sticking. The operator found that the control anemometer was shielded at times depending upon the direction of the wind. He was instructed to move the anemometer to a location which was not shielded by the control station.
Sep, 1981	The operating of the 3 position ammeter switch caused the VAWT to shut down for no reason. After further investigation it was found that the turbine would not shut down when the three position ammeter phase switches were changed provided the turbine was not producing power. Indicates electrical interference between switch and turbine controller. Oil was added to make up for the loss due to the leak.
Oct, 1981	Guy tension display still not operating correctly.
Nov, 1981	Oil leaks are still apparent. The guy tension problem was not resolved. Site visit schedule changed from weekly or less to 2 week intervals.

Dec, 1981	On December 10, 1981, during a regular site visit, B.C. Hydro staff observed one of the spoilers was deployed. It would not latch due to a broken locating dowel on the latch plate. The dowel was replaced and the mounting holes in the spoiler welded. Several days later the spoiler was again observed deployed, with one hinge pin missing. The turbine was shut down from 10 to 27 December, 1981 pending repairs.
Jan, 1982	A replacement hinge pin was received from DAF Indal and installed on the damaged spoiler. However, because the spoiler had been hanging from one hinge, the hinges were no longer aligned and binding resulted. Efforts to straighten the hinge failed. It was decided to put the turbine back into service, recognizing that the spoiler would have to be manually latched should it deploy.
Jan, 1982	Modification to the gear lubrication system to prevent oil fogging inside the power module was made as per DAF Indal instructions. During a regular site visit to read the WHR the display on the continuously running lower recorder was found to be off. This was found to be due to a low battery. A subsequent check later in the month found the WHR to be operating correctly and the battery voltage had returned to normal.
Feb, 1982	Early in the month spoilers were removed, fairings were installed on the blades, and a centrifugal overspeed hydraulic dump valve was installed to back up the existing electrically operated valve.

Apr, 1982	On April 23, 1982 the turbine was shut down at NRC's request, so that the rotor couplings could be checked for cracks. No problems were found. During subsequent testing, noises were heard coming from the upper bearing. It was decided to simply grease this bearing. Found 21 trips on max. wind speed shut down and 1 trip on phase volt shut down.
May, 1982	The turbine was down during some of May, 1982 to check cracks on the rotor shaft. The cut-out wind speed was increased from 35 mph to 40 mph (15.65 to 17.88 m/s) on 25 May, 1982.
Jun, 1982	The turbine was found to be inoperative and would not restart even after the hydraulic dump valve had been reset. The problem was traced to the high/low voltage relay. A new relay was requested from NRC. Three Climet anemometers were installed as part of the annual bearing replacement schedule.
July, 1982	It was observed that one of the display segments on the generate-only recorder had burnt out. This resulted in erroneous readings.
Aug, 1982	B.C. Hydro staff readjusted the centrifugal switch to trip at 3 lb. pull, the previous setting of 1.5 to 2.0 lb. being too light. One of the guy tensions was found to be reading too high and it was recommended that this should be investigated.
Sep, 1982	The dump valve operation was checked.

Oct, 1982	Guy tension display problems are still present. The turnbuckles on the guys were changed based on information from VAWT in Eastern Canada. This resulted in the bull gear lift increasing by 1/16 in. VAWT unit put back in service on 29 October, 1982 after clearing up guy problem by changing bottom clevis on North and West Guy. Unit shut down 12 October, waiting for parts.
Nov, 1982	The turbine was shutdown for approximately two days starting 8 November, 1982 while the hydro lines were checked.
Dec, 1982	Squeaking noises heard near the rotor 16 December, 1982.
Jan, 1983	The upper wind histogram recorder was not operating.
Feb, 1983	Vibration caused solid (brittle) wires in control system to break resulting in shut down of unit. Down time most of month due to waiting for new control package replacement. Waiting time 28 days.
Mar, 1983	New controls installed 4 March. Coupling crack running about 160^0 around found early February. New coupling installed 3 March. Waiting time 7 days. Declared operational 10 March, 1983. Did not reach start up speed in time and therefore tripped. B.C. Hydro line crew inspected power lines for corrision and made many changes to connectors. Work did not make any change to low voltage condition. Control middle anemometer bearing seized.
Apr, 1983	The control anemometer was moved to a better location on 11-13 April as it was previously in the wake of the turbine. New control timing cards were added to the trip indicator panel. Max. start time for motor to reach 700 rpm raised from 35 sec. to 40 sec. on 11 April 1984. Wrong anemometer was installed (6 volt instead of 12 volt). Unit operational on 14 April 1983.

May, 1983	The available time meter was removed for repair.
Aug, 1983	Trip due to motor not reaching 700 rpm in time.
Oct, 1983	Reports indicated that the turbine volt meter was not operating correctly.
Nov, 1983	B.C. Hydro problems at Jordan River prevented VAWT maintenance and monitoring. No data reported for November, December 1983 and January 1984 because of strike at B.C. Hydro.
Feb, 1984	Maintenance was performed 13-15 February, 1984. Modifications were made to the elapsed time meters to include idle time, and available time. The hydraulic and lubrication oils were changed. Bolts on the rotor were tightened.
May, 1984	The anemometers were changed as part of the annual bearing replacement, however the cups were damaged during the replacement. The problem with the upper anemometer was futher investigated and traced to poor wiring between it and the recorder. A new auto control system (card NC 112) was installed. Y-Delta shift changed from 1240 to 1208 rpm on 10 May, 1984 to alleviate possible weak point of the high speed shaft which may have resonance at 60 Hz and xxxxx to delta shift to be quite agressive.
Jul, 1984	Upper anemometer and lower WHR unserviceable. Lower anemometer and upper WHR rewired together to provide operating system and obtain data.
Oct, 1984	On 19 October, 1984 the unit tripped from a shaft overspeed, and when reset a fire broke out in the generator.
Nov, 1984	The turbine did not operate this month awaiting repairs to the generator. It was assumed that the fire of October, 1984 had resulted from grease on the windings on the motor, which ignited when the overspeed trip occurred.

Jan, 1985	Turbine motor/generator was rewound and replaced on January 21, 1985. DAF Indal visited the site to perform maintenance and install motor. All systems were checked and found to be operating correctly. Motor torque low to reach 700 rpm within 40 secs. in low wind conditions. Found not wound properly.
Mar, 1985	The turbine repairs were completed and limited tests were performed to check the control system. A new motor modified at factory, from 440 V to 575 V was installed and found to be satisfactory. DAF Indal were on the site from March 27, 1985 to April 1, 1985. The turbine was left in automatic mode on March 31, 1985. Rewound motor removed and sent to shops for second rewind.
Apr, 1985	The burnt out motor which had been rewound once was rewound a second time but not installed because locked rotor torque did not reach manufacturer's specification of 453 ft lbs and new motor/generator in place was operating well.
Sep, 1985	The power grid transformer voltage tap was adjusted in error to 580 V a.c. instead of 690 V. Error not discovered as voltage was not measured by line crew.
	The 6 month preventative maintenance tasking was completed on the VAWT system. Observations of changes in system performance indicated no improvement due to transformer tap change. The transformer voltage tap was subsequently changed in the other direction by B.C. Hydro line crew to supply 628 V ac to the VAWT motor. Performance observations indicated that under no wind conditions, the motor would now take only 32 seconds to accelerate rotor to 700 rpm. The "run-up time" timer card for the system is to be left unchanged.
	New cup set and replacement/spare anemometers sent to site by T E S Limited.

Jan, 1986	VAWT functioning without incident.
Dec, 1986	VAWT system overhaul performed.

Appendix B
Churchill

AIR DENSITY COMPENSATION FACTORS
BASED ON
A.E.S. NORMALS AT THE CLOSEST A.E.S. STATION

SITE: Churchill

ALTITUDE: 0m CLOSEST A.E.S. STATION: Churchill

STD AIR PRESSURE: 101.33Kpa

	AVERAGE MONTHLY A.E.S. TEMPERATURE T_{avg} °K	COMPENSATION FACTOR f_{comp} $f_{comp} = \frac{288.15}{T_{avg}} \times \frac{\text{Std Air Pressure}}{101.33}$
JANUARY	245.5	1.17
FEBRUARY	247.1	1.17
MARCH	252.6	1.14
APRIL	262.9	1.10
MAY	271.5	1.06
JUNE	279.2	1.03
JULY	284.8	1.01
AUGUST	284.3	1.01
SEPTEMBER	278.4	1.03
OCTOBER	271.5	1.06
NOVEMBER	260.9	1.10
DECEMBER	250.8	1.15

Notes: Compensated Energy Output = Estimated Energy Output x f_{comp}

A.E.S. data obtained from Canadian Climate Normals

Temperature 1951 - 1980 UDC: 551.582(71)

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHURCHILL, MANITOBA

CUT IN WIND SPEED 6.60 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1982				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE										
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD	AVERAGE WIND SPEED	K	AVAIL. WIND ENERGY BETZ LIMIT	EST. GEN. TIME	EST. OUTPUT ENERGY	DOWN TIME *4	STOP TIME *5	IDLE TIME *6	ACTUAL GEN. TIME *7	ACTUAL INPUT ENERGY	ACTUAL OUTPUT ENERGY	ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME	ACTUAL GEN. % OF EST. GEN. TIME	DOWN TIME % OF TOTAL TIME PERIOD	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED
	HR	M/S		KW-HR	HR	KW-HR	HR	HR	HR	HR	KW-HR	KW-HR	KW-HR	%	%	%	%	KW-HR
JAN. *1	737.4	7.2	1.77	29682	3384	5971.4	722.2	0	0	15.2	40	100	N/A	0.34	1.67	.45	97.94	7433.0
FEB. *2	657.3	7.7	3.03	23218	442	7381.4	259	136	6	256	40	4900	4722.5	21.10	66.38	57.92	39.39	7490.8
MAR. *3	701.5	7.7	2.29	27992	407	7899.9	240	184	0	276	45	5445	5535.5	19.45	68.92	67.81	34.25	8504.4
APR.	746.0	6.8	2.02	20876	377	4824.2	192	366	11.5	135	25	1505	1401.4	7.21	31.2	41.28	25.72	5442.8
MAY *9	724.0	5.8	2.10	12878	311	3162.8	724.8	0	0	0	0	0	N/A	0	0	0	100.0	3302.7
JUNE	637.5	4.6	2.39	6422	169	1522.9	638.4	0	6	0	0	0	N/A	0	0	0	100.0	1522.9
JULY *10	758.6	5.0	2.10	8151*10	277	1834.4	144	491	10.9	108.8	65	1125	1248.4	13.8	61.33	47.93	18.99	1844.4
AUG.	750.5	5.2	1.74	7923	197	1367.8	216	397.2	9.1	108.1	65	450	459.2	5.68	32.9	54.87	28.75	1440.1
SEPT.	709.1	7.3	2.59	20817	396.4	6202.3	12	309.5	22.3	362.6	60	5380	5862.2	25.84	86.74	91.47	1.69	6346.8
OCT. *8	668.0	7.0	2.06	20420	298.6	4883.7	336	136.6	33.8	162.1	25	1890	2011.7	9.26	38.7	54.29	50.36	5654.6
NOV.	770.9	7.5	1.97	34658	407.7	9200.1	770.4	0	0	2.0	185	10	17.4	0.03	0.11	0	100.0	10525.0
DEC.	846.3	5.9	1.67	19170	291.9	4746.9	171.6	454	4.7	215.3	160	3040	2860.1	15.86	64.04	73.76	20.25	5263.0
SUM	8707.1	6.48	1.86	232207	6868.6	58997.8	4425.6	2565.3	114.3	1641.1	710	23845	24118.4	10.27	40.42	23.93	50.83	64810.5

NOTES: Explanation on following page.

NOTES ON CHURCHILL 1982

*1 Trips of unknown origin. Operating in manual mode since 21 December 1981. Problem with lube oil and hydraulic pressure and level. Anemometer operating in shadow of turbine.

*2 Unable to get sustained reset in auto mode. VAWT in manual mode from 21 December 1981 until first reliable start in auto mode 12 February 1982.

Actual output of energy taken from net module readings and input energy estimated.

*3 Generate time from "Generate Only" histogram recorder for March and April 1982 was larger than the on-line clocks indicating clocks may be in error.

*4 Down time is an estimated value and is created by searching through data sheets for obvious problems where the generator was shut down.

*5 Stop time is calculated by subtracting the actual generate time, the idle time and down time from the total time in the period.

*6 "Idle Time" is calculated by subtracting "actual generate" time from the "Run Time". Run time data is taken from the generate time meter and includes idle and start up time (i.e. meter sensor connected to hydraulic pump).

Stop time is not included in the definition of run time.

*7 Actual generate time is calculated in the program by adding counts in the "run only" histogram recorder.

*8 The change from plastic cups to steel cups for the anemometers at the beginning of October 1982 resulted in a new calibration curve for the anemometer output signal. Therefore the bin definition for the histogram recorder was appropriately adjusted to reflect this new anemometer calibration.

Shut down VAWT 4 October because of anchor vibration in North guy.

Hydraulic oil level and oil pressure problems caused down time from 8 to 10 October.

*9 Equipment down from 21 April 1982 to 30 June 1982 for main coupling repair.

*10 Removed spoilers and installed centrifugal dump valve 27 July 1982. Manitoba Hydro installed repaired power meters 29 July 1982. Readings of actual output energy for July 1982 are taken from module meter readings and input energy estimated as Hydro meters were defective.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHURCHILL

CUT IN WIND SPEED 6.60
CUT OUT WIND SPEED 15.65 (unless otherwise noted)

YEAR: 1983				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE						ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME	ACTUAL GEN. % OF EST. GEN. TIME	DOWN TIME % OF TOTAL TIME PERIOD	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD HR	AVERAGE WIND SPEED M/S	K	AVAIL. WIND ENERGY BETZ LIMIT KW-HR	EST. GEN. TIME HR	EST. OUTPUT ENERGY KW-HR	DOWN TIME HR	STOP TIME HR	IDLE TIME HR	ACTUAL GEN. TIME HR	ACTUAL INPUT ENERGY KW-HR	ACTUAL OUTPUT ENERGY KW-HR	KW-HR	%	%	%	%	KW-HR
JAN.	689.7	6.3	2.25	18257	315.0	5202.3	0	365.8	16.7	307.2	110	3870.0	4424.4	21.2	74.39	97.5	0	5421.9
FEB.	721.8	6.5	1.98	19633	271.3	5238.6	0	493.4	11.4	217.0	80	2870.0	3006.9 *5	14.6	54.79	80.0	0	5583.1
MAR. *3	738.8	6.0	2.44	14228	272.4	3563.3	0	410.0	16.4	312.0	115	3720.0	3545.9	26.1	104.4	114.5	0	3564.2
APR.	718.4	6.3	2.92	14367	295.4	3929.6	5.3	347.2	18.2	345.7	155	3770.0	3477.3	26.2	95.9	117.0	0.7	3930.0
MAY *1	786.2	6.6	1.94	20490	332.1	5499.6	72.7	331.6	19.1	362.8	95	4915.0	4930.8	24.0	89.37	109.2	9.3	5644.6
JUNE	720.0	4.4	2.41	5548	125.1	931.7	49.5	532.0	9.0	129.0	95	920.0	884.7	16.6	98.74	103.1	10.2	931.7
JULY	729.3	5.4	1.96	9582	181.5	2175.8	384	275.9	3.5	65.9	50	400.0	447.6	4.2	18.38	36.3	52.7	2179.2
AUG.	780.8	5.6	1.83	10939	227.1	2460.3	48	513.8	10.9	208.1	100	1880.0	1860.7	17.2	76.41	91.6	6.1	2497.8
SEPT.	724.2	7.6	1.78	29303	315.5	7102.6	240	332.4	7.6	144.2	170	2540.0	2323.5	8.7	35.76	45.7	33.1	7651.5
OCT. *2	730.4	6.7	2.34	16330	318.2	4504.4	658.4	7.4	3.2	61.4	110	510.0	472.1	3.1	11.32	19.3	90.1	4513.4
NOV. *4	769.8	8.2	2.34	34655	465.7	9194.1	83.2	111.4	65.1	510.2	75	5890.0	6661.6	17.0	64.06	109.6	10.8	9495.3
DEC.	702.8	7.4	2.02	26694	363.8	7387.5	71.3	98.8	77.3	442.0	170	7038.0	5885.9	26.4	95.27	121.5	10.1	7494.6
SUM	8812.2	6.4	1.87	220026	3483.1	57189.8	1612.4	3819.7	258.4	3105.5	1325	38323.0	37921.4	17.4	67.0	89.2	18.3	58907.3

NOTES: Explanation on following page.

NOTES ON CHURCHILL 1983

*1 Data recorded does not allow for an accurate determination of stop and idle time from May to October 1983 inclusive.

*2 On 28 October 1983 the run time meter was replaced and a new data acquisition meter called "available time" was added to the VAWT Controls.

*3 Effective cut-out wind speed adjusted to 40 mph (17.8 m/s).

*4 Effective cut-out wind speed adjusted to 45 mph (20.1 m/s).

*5 "Generate Only" histogram recorder readings were not taken on the month end. Missing 3 days of data.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHURCHILL

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 20.18 m/s

YEAR: 1984				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.	737.4	8.5	2.43	37586	484.7	10533.7	0	125.1	70.0	557.1	215.0	10170.0	10229.5	27.1	96.6	114.9	0.0	10625.5
FEB.*1	699.9	5.6	2.07	15752	283.1	4004.9	24.0	267.2	65.3	339.4	95.0	4230.0	4066.5	26.8	105.6	119.8	3.4	4004.9
MAR.	743.0	5.9	1.72	16308	228.1	3696.1	0	342.6	79.1	319.3	190.0	3437.0	3611.2	22.9	101.1	140.0	0.0	3696.7
APR.	723.1	7.3	2.11	24059	394.9	6484.7	30.5	196.5	64.6	431.5	190.0	5365.0	5287.8	22.3	82.7	109.3	4.2	6541.6
MAY	747.4	5.5	2.51	10432	245.3	2555.6	22.3	363.6	63.9	297.6	100.0	2430.0	2198.8	23.3	95.1	121.3	3.0	2555.6
JUNE*2	684.4	6.1	2.03	12969	242.5	3224.7	530.9	87.0	18.6	48.4	20.0	420.0	390.6	3.2	13.0	8.3	77.5	3224.9
JULY*3	766.2	5.5	2.45	8541	199.9	1609.4	416.1	214.6	32.2	103.3	20.0	330.0	350.5	3.9	20.5	51.7	54.3	1609.4
AUG.	742.3	6.4	1.82	16245	276.7	3813.7	345.5	257.6	38.8	100.4	80.0	850.0	823.1	5.2	21.6	36.3	46.5	3821.0
SEP.	736.1	7.2	2.28	23413	379.6	7034.1	121.7	187.2	34.7	393.0	65.0	6905.0	6324.0	29.5	98.2	103.5	16.5	7034.1
OCT.	734.7	7.9	2.07	31305	412.5	7434.4	122.9	134.5	55.5	367.6	95.0	5095.0	4700.4	16.3	68.5	89.1	16.7	7636.9
NOV.	719.2	6.8	2.23	20052	333.6	5831.2	48.3	205.2	68.4	397.3	140.0	5860	5349.7	29.2	100.5	119.1	6.7	6051.4
DEC.	749.6	7.1	2.34	24371	352.9	6193.2	84.3	191.4	92.4	381.1	275.0	5650	4655.5	23.2	91.2	107.9	11.3	6193.2
SUM.	8783.3	6.7	1.92	241033	3833.8	62415.7	2378.2	2572.5	683.5	3736	1485	51039	91319.7	21.2	81.8	97.5	27.1	62995.2

NOTES: Explanation on following page.

NOTES ON CHURCHILL 1984

*1 Total time in the period is short approximately 7 days due to a suspected histogram recorder failure. Subsequent testing revealed that the recorder was operating correctly. No other explanations have been given as the cause of the lost data.

*2 Turbine shutdown 11.5 hours due to many non-recycleable trips. Remainder of down time due to electrical problem waiting for technician.

*3 Turbine shutdown for 416 hours due to many non-recycleable trips.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHURCHILL

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 20.18 m/s

YEAR: 1985				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN. *2	746.3	7.2	2.76	21646	427.7	5674.4	24.4	159.5	58.3	504.1	15.0	6070.0	5342.2	28.0	107.0	117.9	3.3	5674.4
FEB. *3	679.3	5.3	1.79	11745	198.0	2883.6	23.0	358.6	43.5	252.3	75.0	3260.0	2489.5	27.8	113.1	127.4	3.4	2883.7
MAR.	758.6	6.3	1.93	18714	290.1	4509.8	30.3	331.3	68.1	328.9	105.0	5200.0	4603.6	27.8	115.3	113.4	4.0	4510.9
APR.	717.4	6.2	2.04	14742	283.9	3608.6	0.0	271.3	78.7	369.6	120.0	4110.0	3743.0	27.9	113.9	130.2	0.0	3611.6
MAY	722.3	6.1	2.39	12918	278.9	3338.0	3.0	164.1	180.3	366.9	140.0	2925.0	3124.6	22.6	87.6	131.6	0.4	3338.0
JUNE	735.4	5.2	2.57	7301	169.5	1301.3	48.0	375.9	72.3	239.2	110.0	1355.0	1184.0	18.6	104.1	141.1	6.5	1301.3
JULY	730.1	5.5	2.27	8642	205.0	1835.6	289.4	238.4	62.3	140.0	80.0	620.0	661.3	7.2	33.8	68.3	39.6	1835.6
AUG. *1	572.4	6.1	1.80	10424	184.2	2406.2	551.7	14.8	0.8	5.1	10.0	20.0	27.1	.26	1.13	2.77	96.4	2421.0
SEP.	764.5	6.9	1.65	27574	312.9	5651.9	20.1	218.2	172.5	353.7	210	3820	3241.3	14.0	67.6	113.0	2.6	5971.9
OCT. *4	720.0						227.8	156.8	69.9	265.5	130.0	3385.0					31.64	
NOV. *5	712.7						139.8	227.7	54.9	290.3	140.0	4265.0					19.6	
DEC. *6	392.6	6.2	2.35	10340	180.2	2858.3	31.1	253.6	33.6	449.7	105.0	10250.0					4.05	2858.3
SUM.	8251.6	6.1	1.83	144046	2530.4	34067.7	1388.6	2770.2	895.2	3565.3	1240	45280	24416	31.43	145.75	100.99	16.83	34406.7

NOTES: Explanation on following page.

NOTES ON CHURCHILL 1985

*1 No data from August 2 to August 9 because the wind histogram recorder was left in the "clear" position. Significant down time due to a faulty cable connector. Connector replaced on August 31, 1985.

*2 Downtime due to non-recyclable trips.

*3 Downtime due to semi-annual installation maintenance and installation of new secondary guy anchors.

*4 Both the "Run Only" and "24 Hour" wind histogram recorders were down from October 4 to October 31, 1985, hence insufficient data was available to generate histogram plots. However, actual performance information was available for the site since the turbine was not shut down.

*5 "24 Hour" histogram data was bad due to a faulty anemometer. However, the total bin count does reflect the correct number of calendar days. (November 1 to November 30, 1985)

*6 The site inspector reported that the Wind Histogram Recorder was shut down from, approximately, December 20 to December 31, 1985 because the anemometer was disconnected. In addition, he reported that frost buildup on the cups caused them to either rotate slowly or stop for a number of days.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHURCHILL COMPENSATED

CUT IN WIND SPEED 4.6 m/s
CUT OUT WIND SPEED 20.18 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD	③ AVERAGE WIND SPEED	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT	⑥ EST. GEN. TIME	⑦ EST. OUTPUT ENERGY	⑧ DOWN TIME	⑨ STOP TIME	⑩ IDLE TIME	⑪ ACTUAL GEN. TIME	⑫ ACTUAL INPUT ENERGY	⑬ ACTUAL OUTPUT ENERGY	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME)	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED
	h	m/s		kWh	h	kWh	h	h	h	h	kWh	kWh	kWh	%	%	%	%	kWh
JAN. *1	744.0	7.3	2.12	18314	266.1	4849.3	38.0	281.2	23.3	401.5	85	6630					5.1	4931.9
FEB.	671.6	5.9	2.55	11762	255.7	3047.6	.2	352.2	14.6	304.6	80	2820	3004.8	23.98	92.5	119.1	.03	3047.6
MAR.	745.7	7.2	1.81	27845	356.0	6296.9	3.0	300.9	10.0	431.8	140	5520	5600.4	19.82	87.7	121.3	.04	6539.3
APR.	744.0	7.1	2.51	19546	358.0	5684.6	457.9	67.7	21.3	197.1	40	3030	2952.5	15.50	53.3	55.0	61.5	5684.9
MAY	720.0	5.3	2.35	9502	204.4	2235.0	720.0					*2						2235.0
JUNE	719.6	6.6	2.02	17999	317.2	5106.6	719.6					*2						5121.1
JULY *3	765.6	6.5	2.08	16211	340.2	4289.5	514.4	244.4	2.3	4.5	5	50	40.7	0.31	1.2	1.3	67.2	4296.2
AUG.	716.5	7.1	1.78	23520	324.6	6008.7	377.2	131.9	35.4	172.0	75	1860	1938.9	7.91	31.0	53.0	52.6	6051.3
SEP. *4	723.1	6.7	1.95	15077	235.9	3955.3	93.9	375.5	27.6	226.1	110	1840	1880.0	12.20	46.5	95.9	13.0	3957.0
OCT.	740.4	8.0	1.88	36143	415.3	8936.3	152.1	298.6	11.3	278.4	70	4150	4052.0	11.48	46.4	67.0	20.5	9302.6
NOV. *5	588.3	7.7	2.16	22341	327.6	6583.3	51.3	*6	*6	372.7	110	567	4828.9	2.54	8.6	113.8	8.7	6591.6
DEC.	743.5	7.3	2.58	24275	395.6	7684.4	213.1	*7	*7	308.5	170	4615	5158.6	19.01	60.1	78.0	28.7	7684.4
SUM.	8622.3	6.9	1.93	242535	3796.6	64677.5	3340.1	2052.4	145.8	2697.2	885	31082	29456.6	12.8	48.1	71.0	38.7	65442.9

NOTES: Explanation on following page.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL CHURCHILL

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 20.18 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWn
JAN. *1	744.0	7.3	2.12	18314	266.1	4144.7	38.0	281.2	23.3	401.5	85	6630					5.1	4215.3
FEB.	671.6	5.9	2.55	11762	255.7	2604.8	.2	352.2	14.6	304.6	80	2820	2568.2	23.98	108.3	119.1	.03	2604.8
MAR.	745.7	7.2	1.81	27845	356.0	5523.6	3.0	300.9	10.0	431.8	140	5520	4912.6	19.82	99.9	121.3	.04	5736.2
APR.	744.0	7.1	2.51	19546	358.0	5167.8	457.9	67.7	21.3	197.1	40	3030	2684.1	15.50	58.6	55.0	61.5	5168.1
MAY	720.0	5.3	2.35	9502	204.4	2108.5	720.0					*2						2108.5
JUNE	719.6	6.6	2.02	17999	317.2	4957.9	719.6					*2						4971.9
JULY *3	765.6	6.5	2.08	16211	340.2	4247.0	514.4	244.4	2.3	4.5	5	50	40.3	0.31	1.2	1.3	67.2	4253.7
AUG.	716.5	7.1	1.78	23520	324.6	5949.2	377.2	131.9	35.4	172.0	75	1860	1919.7	7.91	31.3	53.0	52.6	5991.4
SEP. *4	723.1	6.7	1.95	15077	235.9	3840.1	93.9	375.5	27.6	226.1	110	1840	1825.2	12.20	47.9	95.9	13.0	3841.7
OCT.	740.4	8.0	1.88	36143	415.3	8430.5	152.1	298.6	11.3	278.4	70	4150	3822.6	11.48	49.2	67.0	20.5	8776.0
NOV. *5	588.3	7.7	2.16	22341	327.6	5984.8	51.3	*6	*6	372.7	110	567	4389.9	2.54	9.5	113.8	8.7	5992.4
DEC.	743.5	7.3	2.58	24275	395.6	6682.1	213.1	*7	*7	308.5	170	4615	4485.7	19.01	69.1	78.0	28.7	6682.1
SUM.	8622.3	6.9	1.93	242535	3796.6	59641.0	3340.1	2052.4	145.8	2697.2	885	31082	26648.3	12.8	52.1	71.0	38.7	60342.1

NOTES: Explanation on following page.

NOTES ON CHURCHILL 1986

*1 Due to an accidental reset of the wind histogram recorder, plus functional problems with the anemometers, the histogram data is valid for only 470.9 hours of the total 744.0 hours in the period January 1 to January 31, 1986. The estimated output energy from the generate only histogram covers the period January 21 to January 31, 1986. Actual performance data is for the full period January 1 to January 31, 1986.

*2 Broken guy wire, turbine not running.

*3 Guy wire replaced, turbine not able to run unattended due to guy wire vibration.

*4 One week of data was accidently lost. The reported data covers the period September 1-5, September 12-30.

*5 No data was collected between November 14 and November 19.

*6 Stop and idle times can not be reported until the run clock is repaired.

*7 Run time clock started December 7, 1986.
Reported Run time for period = 303.7 hours
Reported Generate time for period = 308.5 hours
The system clock is still in error since the reported run time is less than the generate time (Run time = Generate + Idle time).

MONTHLY AVERAGE WIND SPEED
AND WEIBULL PARAMETER "K"
AS CALCULATED FROM CONTINUOUSLY
RUNNING WIND HISTOGRAM RECORDER

SITE NAME: CHURCHILL

YEAR: 1986

APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January *1	744.0	7.3	2.12	0.011
February	671.6	5.9	2.55	0.009
March	745.7	7.2	1.81	0.024
April	744.0	7.1	2.51	0.006
May	720.0	5.3	2.35	0.015
June	719.6	6.6	2.02	0.018
July	765.6	6.5	2.08	0.017
August	716.5	7.1	1.78	0.027
September *2	723.1	6.7	1.95	0.022
October	740.4	8.0	1.88	0.017
November *3	588.3	7.7	2.16	0.010
December	743.5	7.3	2.58	0.005
YEAR	8,622.3	6.9	1.93	0.021

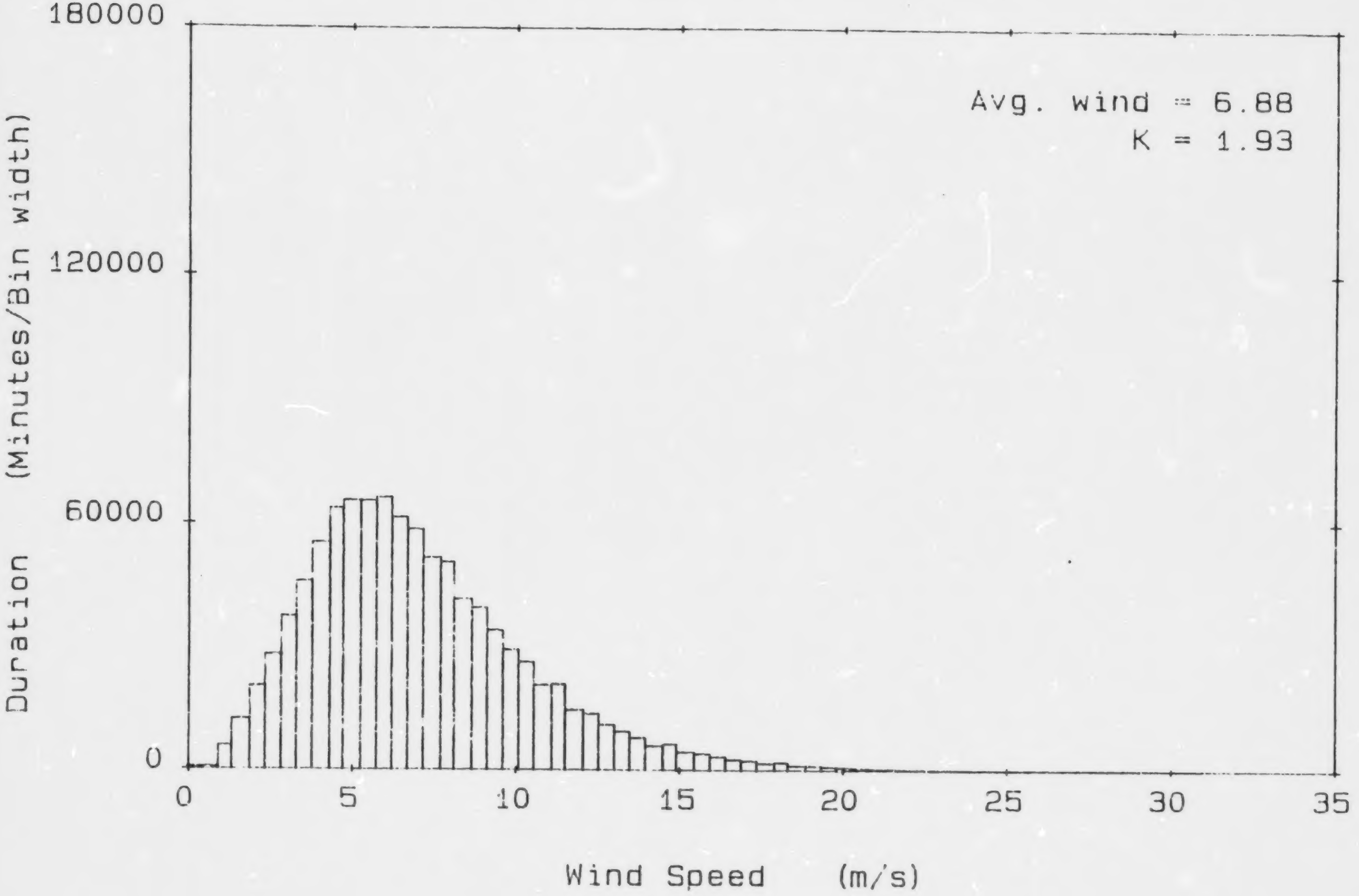
Notes: *1 Seven days of counts were lost due to an accidental reset of the wind histogram recorder. Four days of counts were lost due to work on the wind histogram recorders.

*2 One week of data was accidently lost. The reported data covers the period Sept. 1-5, Sept. 12-30.

*3 No data was collected between November 14 and 19.

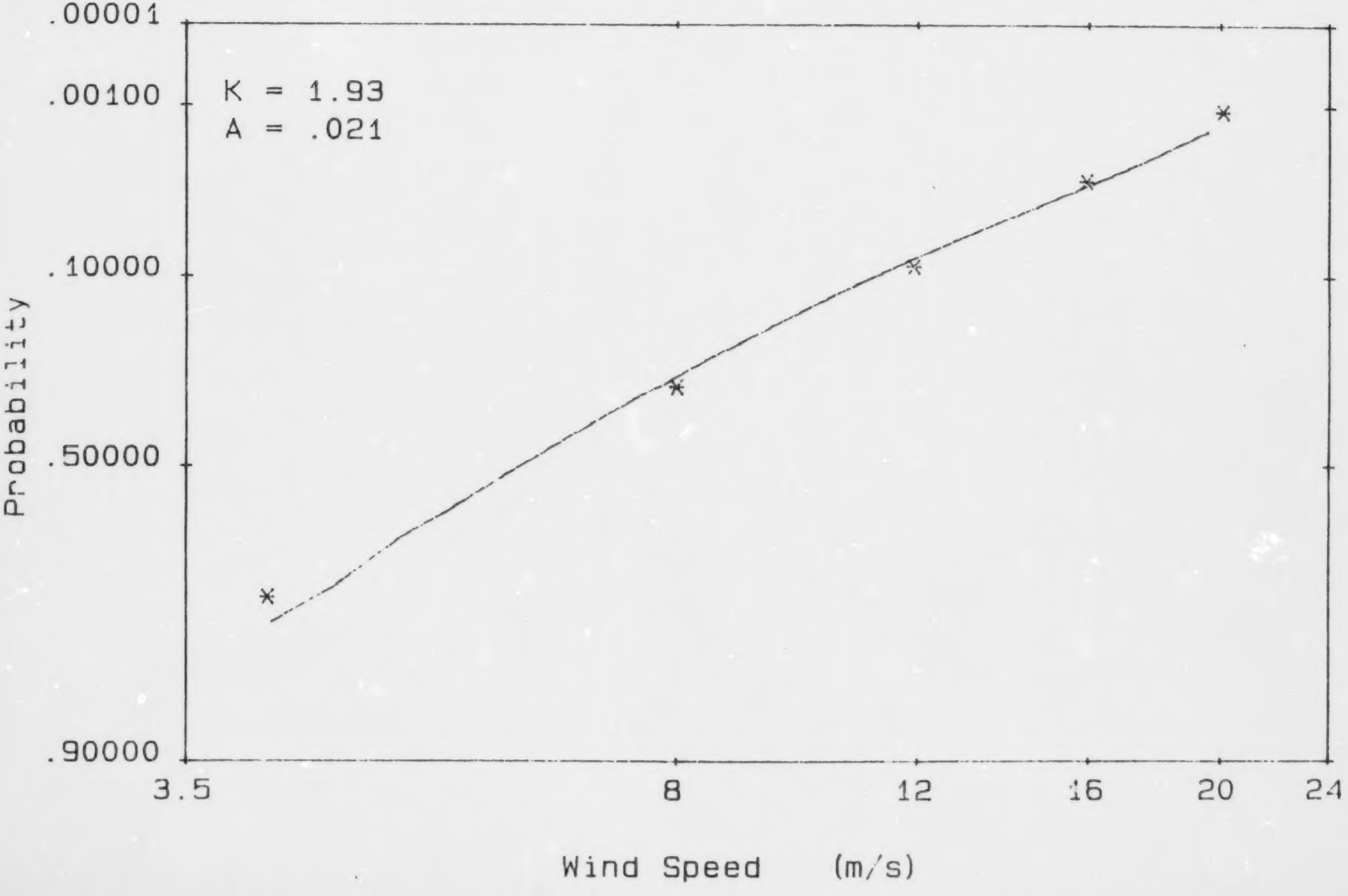
CHURCHILL

January 1 1986 to December 31 1986



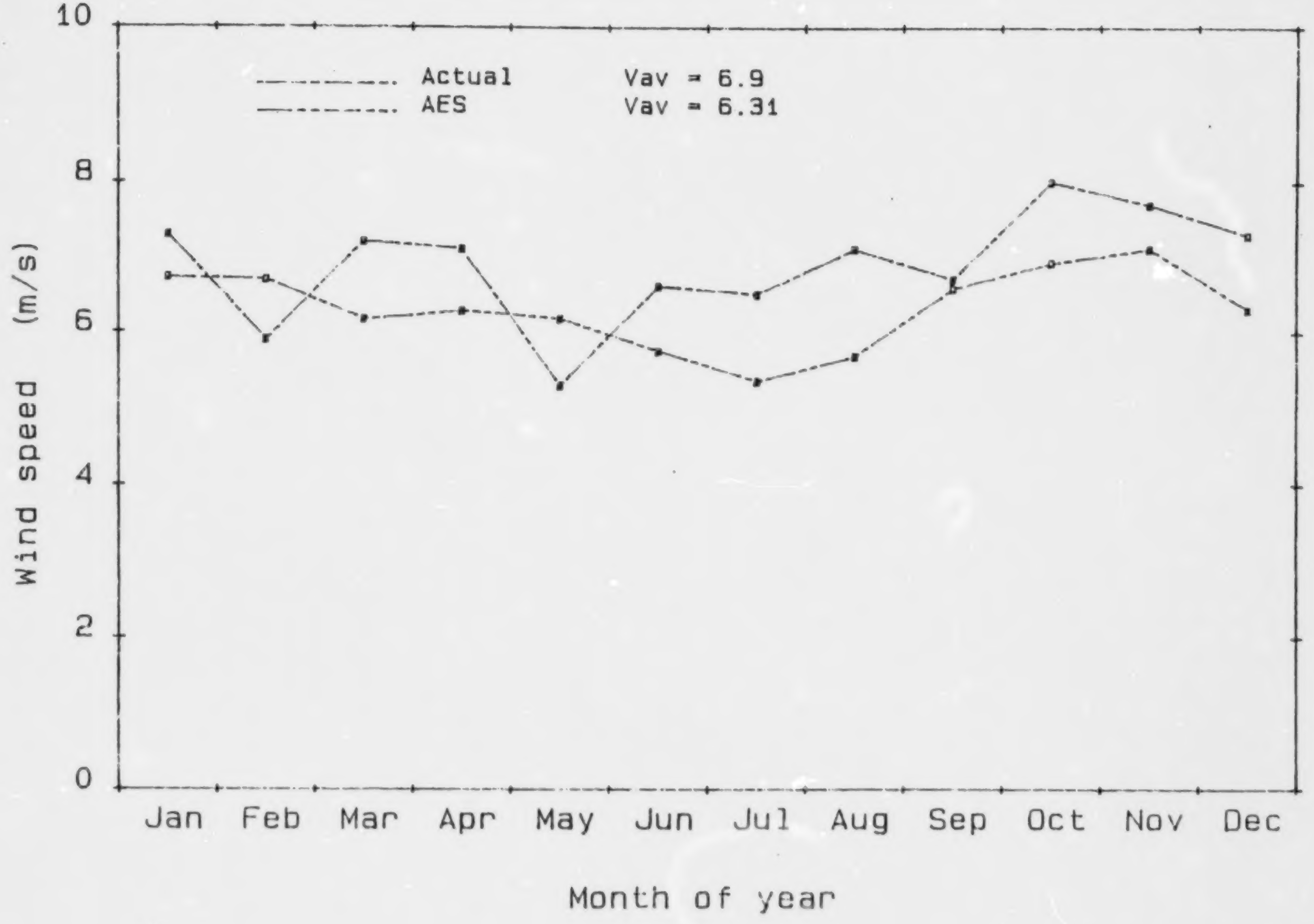
CHURCHILL

January 1 1986 to December 31 1986



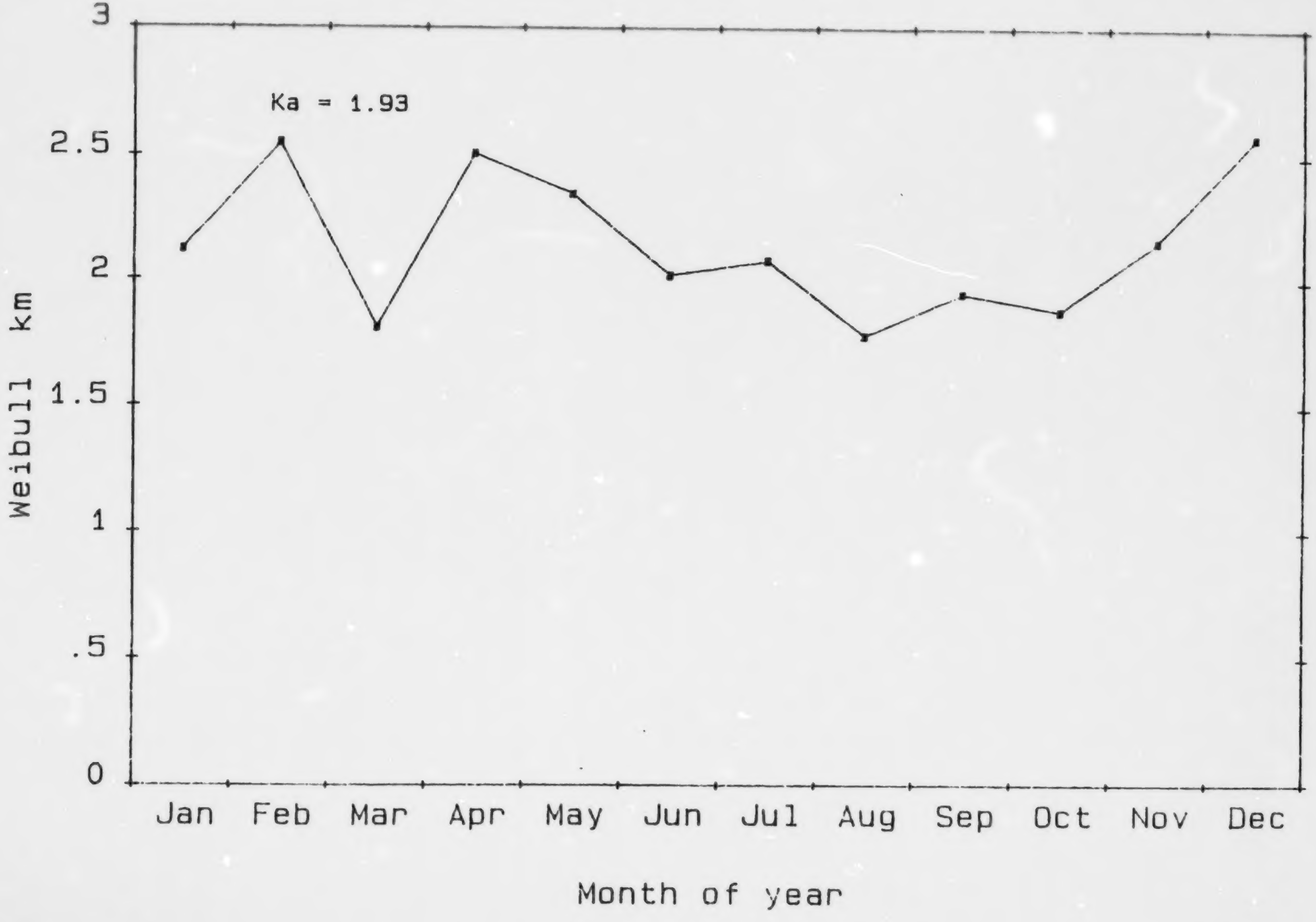
COMPARISON OF AVERAGE WIND SPEEDS

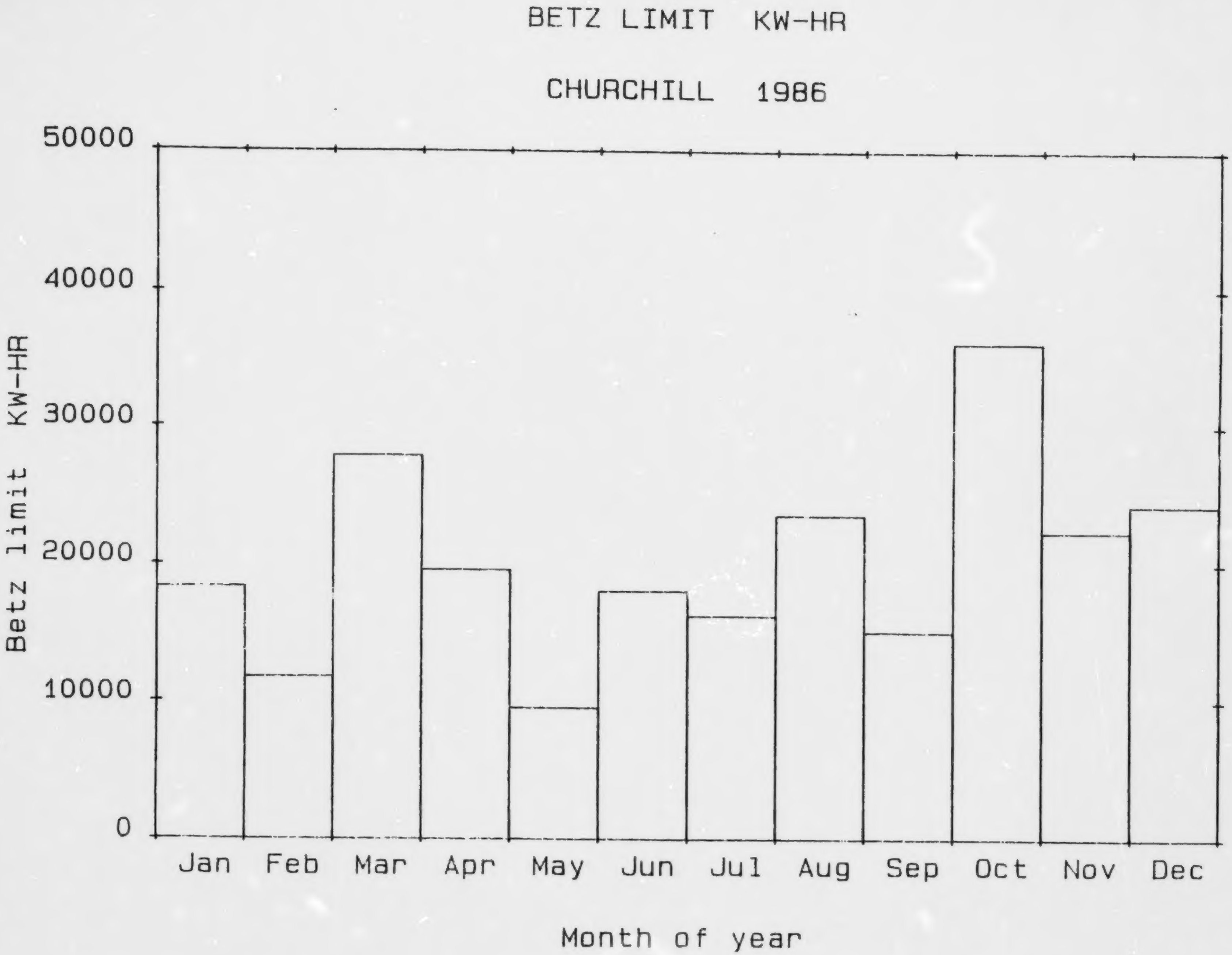
CHURCHILL 1986



WEIBULL PARAMETER km VS month

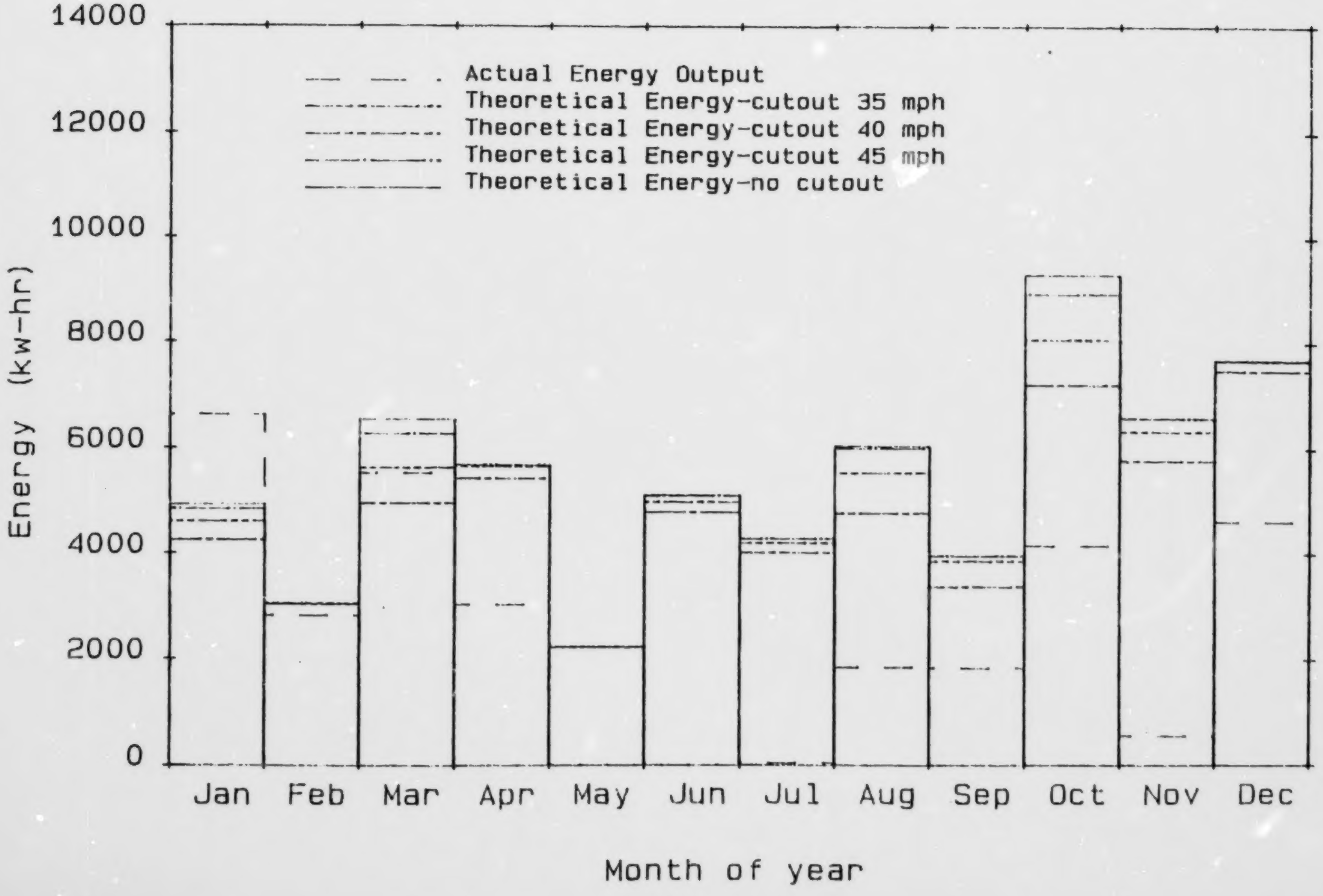
CHURCHILL 1986




BETZ LIMIT KW-HR
CHURCHILL 1986
Betz limit KW-HR
50000
40000
30000
20000
10000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month of year

TURBINE THEORETICAL ENERGY KW-HR

CHURCHILL 1986



VAWT SYSTEM NOTES: CHURCHILL

The following notes summarize turbine operational problems and failures as reported to T E S Limited from the site operator's data sheets.

Jan, 1982	Notes found on the data sheets indicated that the motor shaft key had come out of the shaft. This was replaced the same day.
	Control anemometer in the shadow of turbine with SSW winds, therefore there is a loss of "Actual Energy" not being generated. Estimated energy higher than actual energy generated.
Mar, 1982	On March 19, 1982 the VAWT was shutdown due to problems with the north guy tension. The meter for this guy was reading too high. This problem was persistent throughout the month.
Apr, 1982	The VAWT was shut down for repairs this month. Coupling problems were discovered on April 21, 1982. VAWT shut off overnight at various times due to high S-E winds.
May, 1982	Icing on the anemometer, turbine blades, and the locks caused difficulties during the month. No major problems were apparent.
June, 1982	The problem with ice build-up persisted this month. The system was shutdown on June 30, 1982 for repairs to the coupling. Repairs were completed on July 1, 1982.
July, 1982	On July, 19, 1982 the output meter was found to be inoperative. This meter was replaced on July 20, 1982.

Aug, 1982	The north guy turn-buckle was found to be broken near the tension sensor on 23 August. The turn-buckle was replaced on Aug 31, 1982.
Sep, 1982	Hydraulic oil level problems. The dump valve was checked on Sep 24, 1982. Leakage was found under the cover plate. The lid was taped up on the same day.
Oct, 1982	Some problems were found with the hydraulic pressure. On October 14, 1982 the VAWT was shutdown due to excessive vibration in the north guy.
Nov, 1982	On November 5, 1982 the anemometer cups were found to be frozen and would not turn. The anemometers were replaced on November 18, 1982.
Dec, 1982	On December 10, 1982 a non-recoverable trip occured. The lubrication filter was also found to be loose and leaking oil. This filter was tightened and the leaking stopped.
Jan, 1983	More non-recoverable trips occured this month.
Mar, 1983	Reasons for the persistent non-recoverable trips are still unknown.
Apr, 1983	On April 8, 1983 the net power module was found damaged and unusable.
May, 1983	On May 10, 1983 the turbine was shut down due to icing problems on the rotors. A non-recoverable trip occured during the month.
Jun, 1983	Down time high this month due to anemometer problem. Awaiting replacement.

Aug, 1983	A leak in the pump pressure indicator was found and some oil was being lost. Down time high due to severe thunderstorm and shutdown of anemometer.
Sep, 1983	Operating time was lost due to a non-recoverable trip. Part of down time (61 hours) due to time waiting for replacement pc board.
Oct, 1983	Down time high due to time spent waiting for repair of power supply.
Nov, 1983	More non-recoverable trips occured. It was suspected that this was as a result of the upper bull gear limit being reached. The system was shut down because of the vibrations in the guys.
Dec, 1983	Part of down time (66 hours) due to Manitoba Hydro shut down. Remainder of down time due to cold effect on meter.
Feb, 1984	The net power module was not working.
Apr, 1984	It was reported that some operating time was lost due to a non-recyclable trip which occured during high winds. Also VAWT deliberately shut down due to icing and rotor unable to reach 700 rpm and would recycle automatically after trip.
May, 1984	High winds caused the upper speed limit to be reached and the controller shut the turbine down. This trip resulted in the loss of approximately 6 hours of operation.
June, 1984	More non-recoverable trips occured this month.

July, 1984	It was reported that the turbine suffered from many non-recoverable trips. The damaged power module was disconnected. DAF Indal visited the site to institute repairs to the auto controls and to perform the six month maintenance tasks.
Aug, 1984	Many non-cycable trips.
Sep, 1984	Many non-recoverable trips occured. Problem with non-recyclable trips solved by changing the oil viscosity. Part of downtime (14 hours) due to utility shutdown.
Oct, 1984	Turbine operated well during the month. 72 hours down time due to problems encountered with anemometer replacement.
Nov, 1984	Bull Gear limit trips occurred during the month as a result of colder temperatures which caused the guy tensions to increase. The operator adjusted the guy turnbuckles to compensate for this. No major problems were encountered. Down time due to non-recycable trips.
Dec, 1984	No major problems occurred. Some adjustments were made to the bull gear lift. Down time due to improper guy adjustment.
Feb, 1985	The VAWT ran well this month with few problems.
Mar, 1985	DAF Indal visited the site to install new safety chains and anchor plates on the guy anchors and foundations. DAF Indal felt that the foundations were questionable and that they should be replaced to provide better safety. Scheduled maintenance tasks were also performed as it was felt that there may not be many future trips planned to the site.

Jul, 1985	The site inspector reported on July 19, 1985 that the anemometer signal cable connector had become defective due to surface corrision. The connector was repaired temporarily, however, the site inspector indicated that subsequent histogram readings appeared low. The system was shut down for approximately 12 days during the month of July. A new connector was shipped to Churchill on August 26, 1985.
Aug, 1985	A new cable connector was installed at this site on August 31, however, during the period August 1 to August 31 the turbine had to be shut off on August 9 until the new connector was installed.
Oct, 1985	The site inspector informed us that both wind histogram recorders were rendered inoperative due to a series of hydro problems. Replacement units were sent to him on October 21, 1985. Subsequent hydro problems caused another failure in one of the wind histogram recorders, however, the site manager was not sure if it was the recorder or the anemometer. Therefore, a replacement anemometer and WHR was sent to the site on November 7, 1985.
Dec, 1985	The site inspector informed us that the anemometer for the "24 Hour" wind histogram recorder seemed bad so he intends to replace it as soon as possible. Also, the "Generate Only" wind histogram recorder will not be operational until an interface card, which connects to the recording unit, is repaired by Daf Indal.
Jan, 1986	The VAWT's operational, however, there was a problem with the control anemometer around December 20. The anemometer was replaced December 31, 1985.

Feb, 1986	The site inspector indicated that VAWT was functioning correctly, however, he requires some new batteries for his wind histogram recorders. Four new batteries were shipped on February 24, 1986.
Apr, 1986	A broken guy wire was found. The turbine was shut down.
May, 1986	The turbine was still inoperable. The broken guy wire has not been replaced.
Jul, 1986	Although the guy wire was repaired on 20 July, the turbine has not yet been able to operate for longer than a few hours because of guy wire vibration.
Sep, 1986	Hydraulic pressure adjusted a number of times during the month. VAWT shutdown a number of times due to excessive guy vibration. Anemometer pole lowered during 80 mph wind to prevent damage.
Nov, 1986	The run clock appears to be malfunctioning and may be replaced.
Dec, 1986	Turbine turned off due to high lube oil pressure. New run time clock installed December 7, 1986. Run only WHR off December 5, restarted December 13. VAWT turned off for repairs December 13 and 14.

Appendix C
Rankin Inlet

AIR DENSITY COMPENSATION FACTORS
BASED ON
A.E.S. NORMALS AT THE CLOSEST A.E.S. STATION

SITE: Rankin Inlet

ALTITUDE: 0m

CLOSEST A.E.S. STATION: Whale Cove

STD AIR PRESSURE: 101.33Kpa

	AVERAGE MONTHLY A.E.S. TEMPERATURE T_{avg} °K	COMPENSATION FACTOR f_{comp} $f_{comp} = \frac{288.15}{T_{avg}} \times \frac{\text{Std Air Pressure}}{101.33}$
JANUARY	241.6	1.193
FEBRUARY	243.1	1.185
MARCH	247.6	1.164
APRIL	259.0	1.113
MAY	267.6	1.077
JUNE	275.8	1.045
JULY	281.4	1.024
AUGUST	281.9	1.022
SEPTEMBER	279.6	1.031
OCTOBER	269.5	1.069
NOVEMBER	257.0	1.121
DECEMBER	248.1	1.161

Notes: Compensated Energy Output = Estimated Energy Output x f_{comp}

A.E.S. data obtained from Canadian Climate Normals

Temperature 1951 - 1980 UDC: 551.582(71)

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL RANKIN INLET

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1984				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD	③ AVERAGE WIND SPEED	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT	⑥ EST. GEN. TIME	⑦ EST. OUTPUT ENERGY	⑧ DOWN TIME	⑨ STOP TIME	⑩ IDLE TIME	⑪ ACTUAL GEN. TIME	⑫ ACTUAL INPUT ENERGY	⑬ ACTUAL OUTPUT ENERGY	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY	⑮ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME)	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED
	h	m/s		kWh	h	kWh	h	h	h	h	kWh	kWh	kWh	%	%	%	%	kWh
JAN.*1																		
FEB.*1																		
MAR.*1																		
APR.*1																		
MAY *1																		
JUNE*1																		
JULY*1																		
AUG.*1																		
SEP.*1																		
OCT.*2	190.3	9.0	3.19	8962	140.7	2565.8												2839.5
NOV.	768.1	7.4	2.05	28388	394.2	6650.1												7676.8
DEC.																		
SUM.	958.4	7.6	2.21	37350	534.9	9215.9												10516.3

NOTES: Explanation on following page.

NOTES ON RANKIN INLET 1984

*1 Site installation not complete.

*2 Data received covers the period from September 26, 1984 to October 14, 1984.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL RANKIN INLET

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1985				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD	③ AVERAGE WIND SPEED	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT	⑥ EST. GEN. TIME	⑦ EST. OUTPUT ENERGY	⑧ DOWN TIME	⑨ STOP TIME	⑩ IDLE TIME	⑪ ACTUAL GEN. TIME	⑫ ACTUAL INPUT ENERGY	⑬ ACTUAL OUTPUT ENERGY	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME)	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED
	h	m/s		kWh	h	kWh	h	h	h	h	kWh	kWh	kWh	%	%	%	%	kWh
JAN. *1																		
FEB. *1																		
MAR. *1																		
APR. *1																		
MAY *1																		
JUNE*2	863.8	6.4	2.15	18217	326.0	5085.2												5345.4
JULY*3	223.1	6.3	1.99	5629	76.4	1517.1												1641.8
AUG.	861.2	7.7	1.60	39854	334.2	6336.6												9314.2
SEP.*4	454.2	9.7	2.61	30633	312.8	6995.6												8525.6
OCT.*5	437.1	8.1	1.98	20926	226.3	4367.6												5556.5
NOV.*6	661.3	9.6	1.80	63930	345.4	7702.8												12104.6
DEC.*7	843.5	6.8	1.51	36323	329.8	6097.6												8068.6
SUM.	4344.2	7.72	1.71	21551.2	1950.9	38102.5												50556.7

NOTES: Explanation on following page.

NOTES ON RANKIN INLET

*1 No data received.

*2 Data period from May 30 to July 5, 1985.

*3 Data period from July 15 to July 25, 1985.

*4 Missing 12 days of data from September 6 to September 18, 1985 because the Wind Histogram Recorder was reset accidently.

*5 Data period from September 31 to October 18, 1985.

*6 Data period from October 19 to November 15, 1985.

*7 Data period from November 16 to December 20, 1985.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL RANKIN INLET COMPENSATED

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.*1	676.9	2.6	0.61	24286	89.2	1929.4												3399.6
FEB. *2																		
MAR. *3																		
APR. *4	490.7	6.1	2.83	9404	207.1	3163.1												3163.4
MAY *5	985.0	7.4	1.63	46659	404.3	7958.7												11029.9
JUNE *5	362.6	5.8	2.70	5342	121.2	1574.5												1575.1
JULY	601.4	5.9	2.24	9244	181.1	2433.1												2490.3
AUG. *6	1007.3	8.2	1.88	50007	479.0	10214.6												13629.9
SEP.*7	407.2	6.8	3.12	8498	197.8	2860.6												2861.0
OCT. *8	927.8	7.9	1.68	49252	429.2	9660.7												13081.7
NOV. *9																		
DEC. *9	1197.9	7.1	1.94	42112	568.7	11909.3												13545.7
SUM.	6656.8	6.7	1.63	244804	2677.6	51704.0												64776.6

NOTES: Explanation on following page

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL RANKIN INLET

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.*1	676.9	2.6	0.61	24286	89.2	1617.3												2849.6
FEB. *2																		
MAR. *3																		
APR. *4	490.7	6.1	2.83	9404	207.1	2842.0												2842.2
MAY *5	985.0	7.4	1.63	46659	404.3	7389.7												10241.3
JUNE *5	362.6	5.8	2.70	5342	121.2	1506.7												1507.3
JULY	601.4	5.9	2.24	9244	181.1	2376.1												2431.9
AUG. *6	1007.3	8.2	1.88	50007	479.0	9994.7												13336.5
SEP. *7	407.2	6.8	3.12	8498	197.8	2774.6												2775.0
OCT. *8	927.8	7.9	1.68	49252	429.2	9037.1												12237.3
NOV. *9																		
DEC. *9	1197.9	7.1	1.94	42112	568.7	10257.8												11667.3
SUM.	6656.8	6.7	1.63	244804	2677.6	47796.0												59888.4

NOTES: Explanation on following page.

NOTES ON RANKIN INLET 1986

*1 The site inspector reported that the anemometer was frozen for part of this report period, hence histogram data should be considered invalid.

*2 No data received. Anemometer and cups were reported frozen. No data was available during the month.

*3 No data received due to icing problems.

*4 Recorder was reset to count on April 17, 1986.

*5 No reading was taken at the end of May. Data reported as May covers the six week period ending June 18. Data reported as June covers the two week period ending July 3.

*6 The data received covers a 42 day period from July 29 to September 8.

*7 Data appears to be valid, however, the raw data covering the period September 9 to September 29 is short by 96 hours of counts.

*8 The data noted as missing in note 7 above has been reported this month.

*9 Data reported for the period November 4, 1986 to December 23, 1986.

MONTHLY AVERAGE WIND SPEED
AND WEIBULL PARAMETER "K"
AS CALCULATED FROM CONTINUOUSLY
RUNNING WIND HISTOGRAM RECORDER

SITE NAME: RANKIN INLET

YEAR: 1986

APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January *1	676.9	2.6	0.61	0.586
February *2				
March *3				
April *4	490.7	6.1	2.83	0.005
May *5	985.0	7.4	1.63	0.033
June *5	362.6	5.8	2.70	0.007
July	601.4	5.9	2.24	0.016
August*6	1007.3	8.2	1.88	0.016
September *7	407.2	6.8	3.12	0.002
October *8	927.8	7.9	1.68	0.027
November *9				
December *9	1197.9	7.1	1.94	0.019
YEAR	6656.8	6,7	1,63	0.038

Notes: *1 The site inspector reported that the anemometer was frozen for part of this report period, hence histogram data should be considered invalid.

*2 No data received. Anemometer and cups were frozen.

*3 No data received due to icing problem.

*4 Recorder was reset to count on April 17, 1986.

*5 Data reported as May covers the six week period ending June 18, June ends July 3.

*6 The data received covers a 42 day period from July 29 to September 8th.

*7 4 days of data missing out of 21 days in the period.

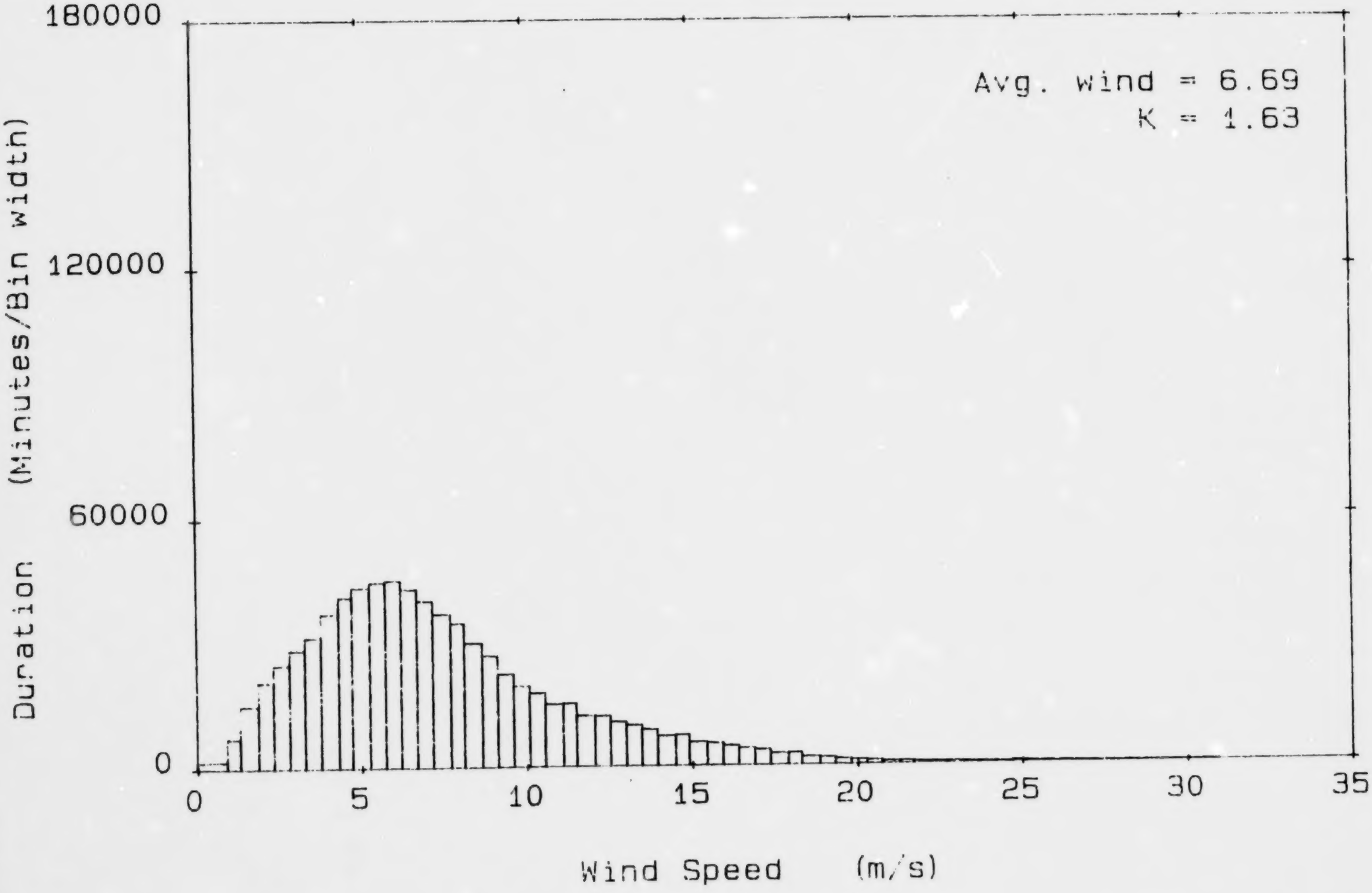
*8 The data reported missing under note 7 above has been reported this month.

(continued)

Notes: *9 Data covers the period November 4, 1986 to December 23, 1986

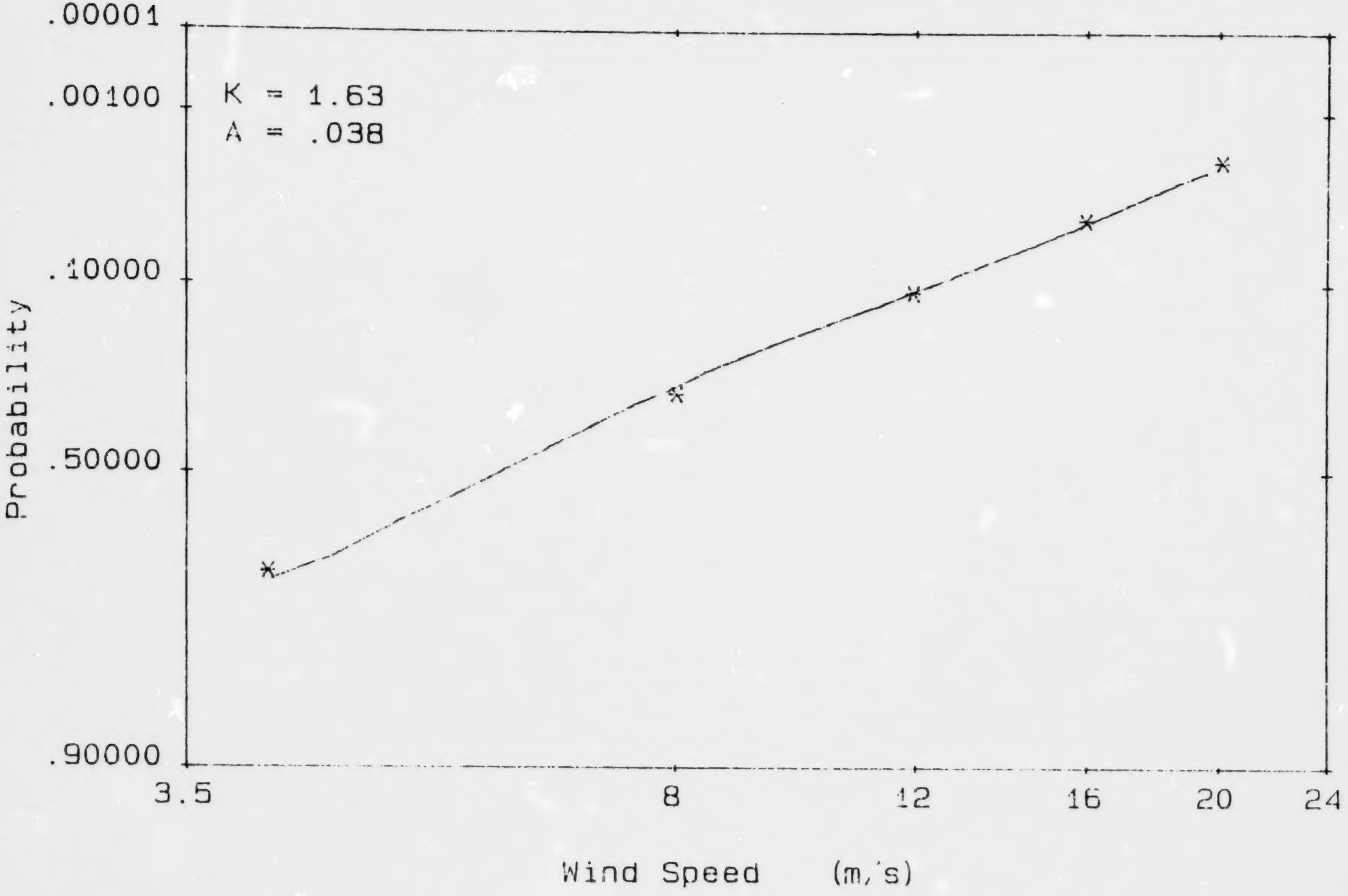
RANKIN INLET

December 21 1985 to December 23 1986



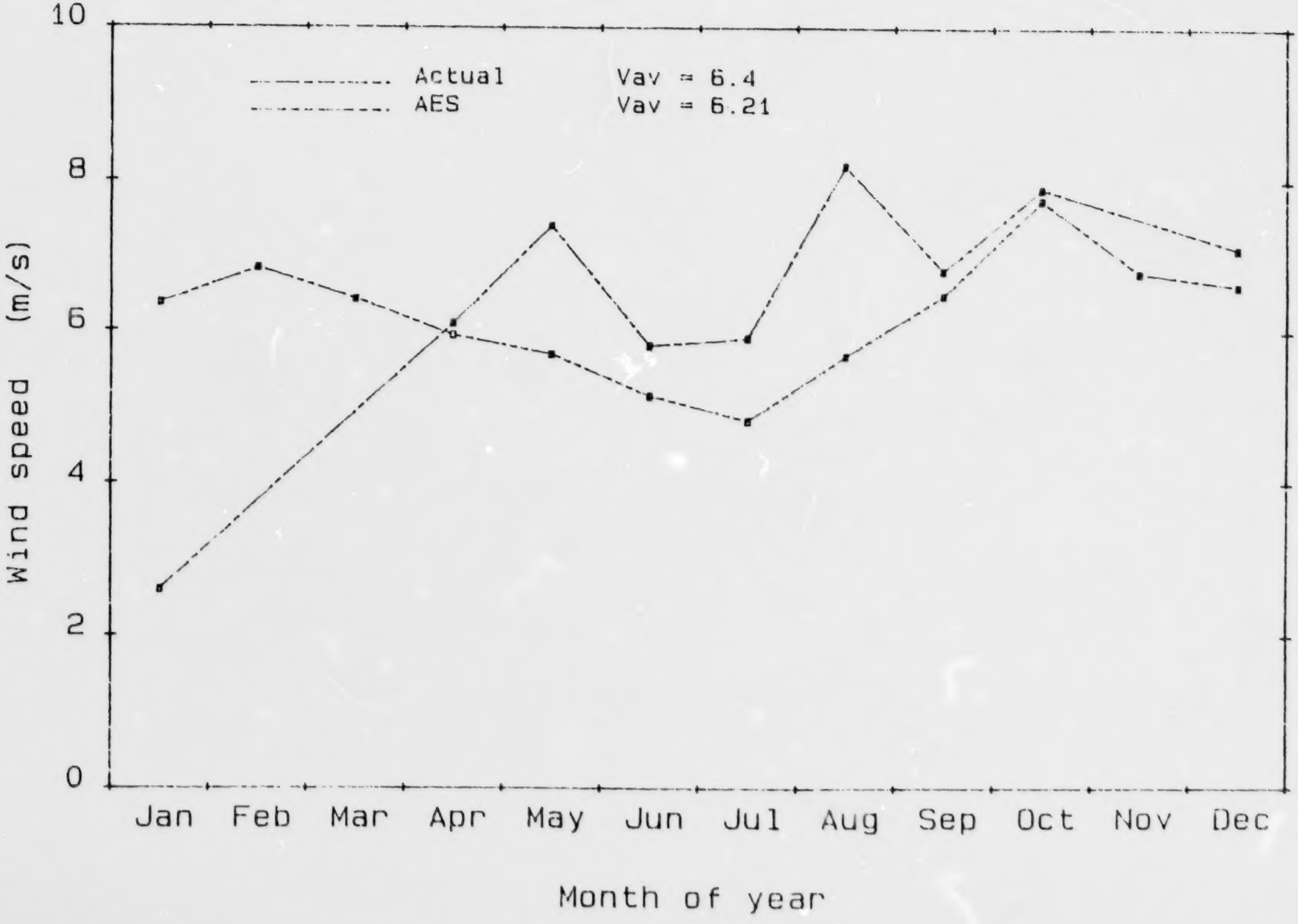
RANKIN INLET

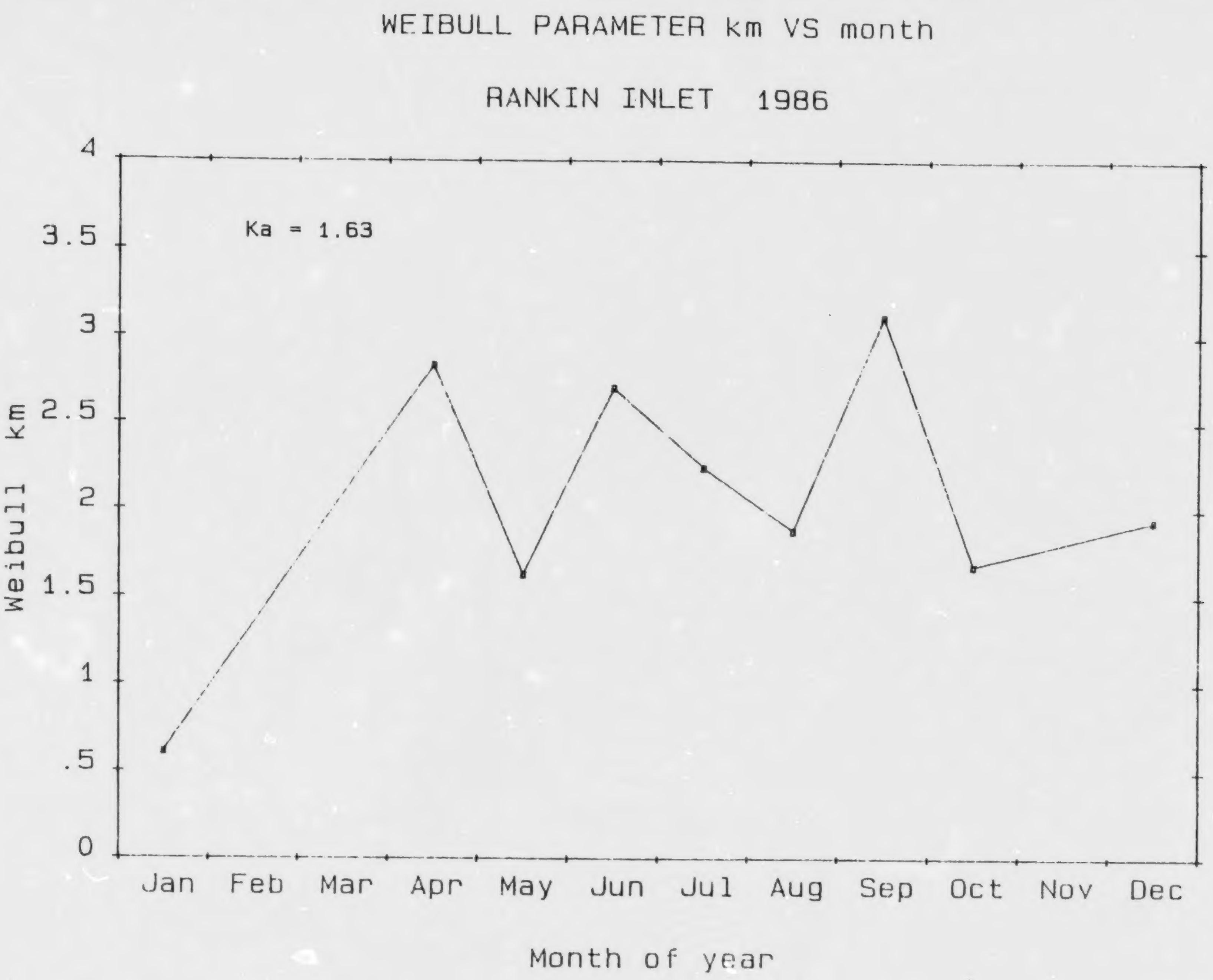
December 21 1985 to December 23 1986



COMPARISON OF AVERAGE WIND SPEEDS

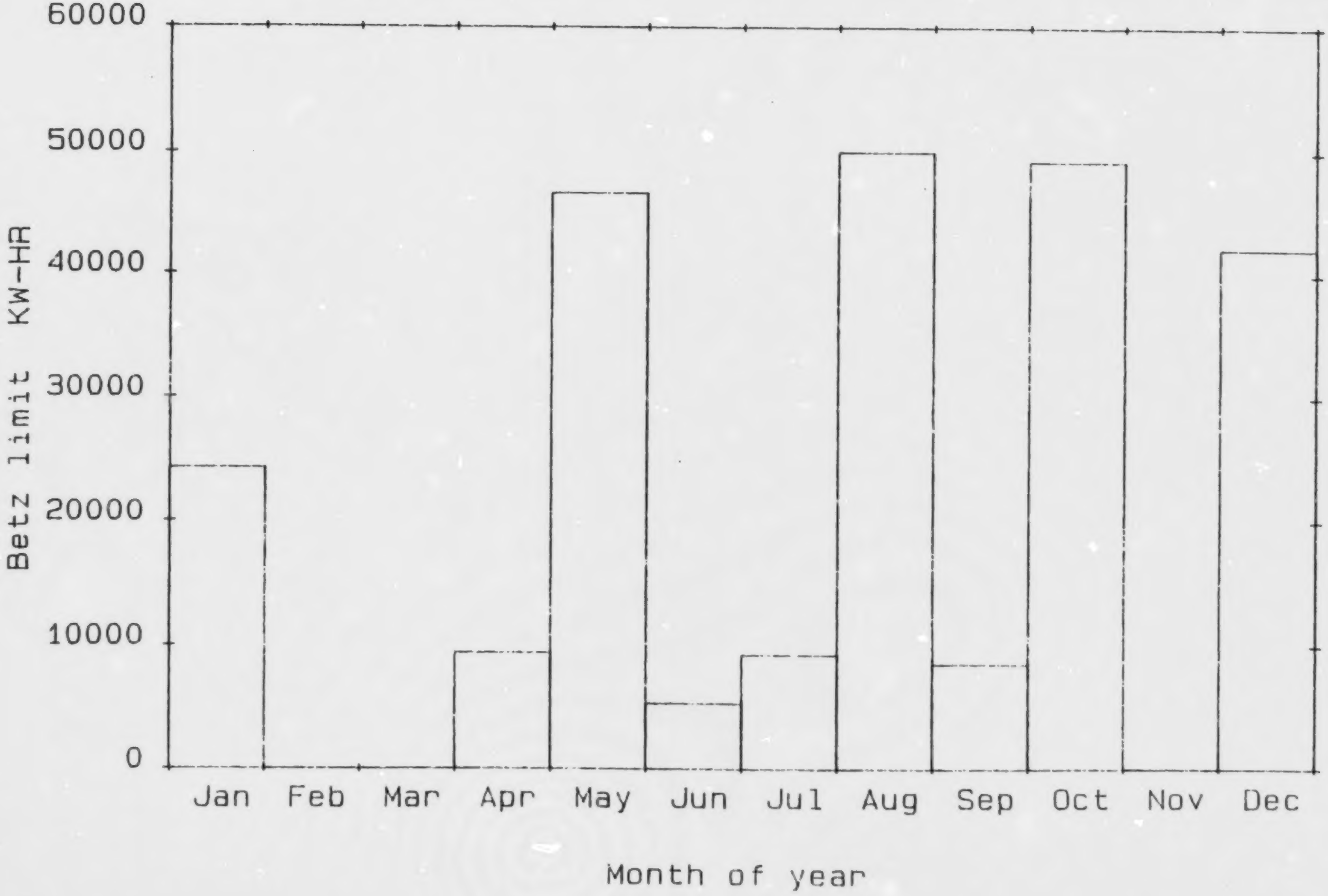
RANKIN INLET 1986




WEIBULL PARAMETER km VS month
RANKIN INLET 1986
Ka = 1.63
Weibull km
4
3.5
3
2.5
2
1.5
1
.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month of year

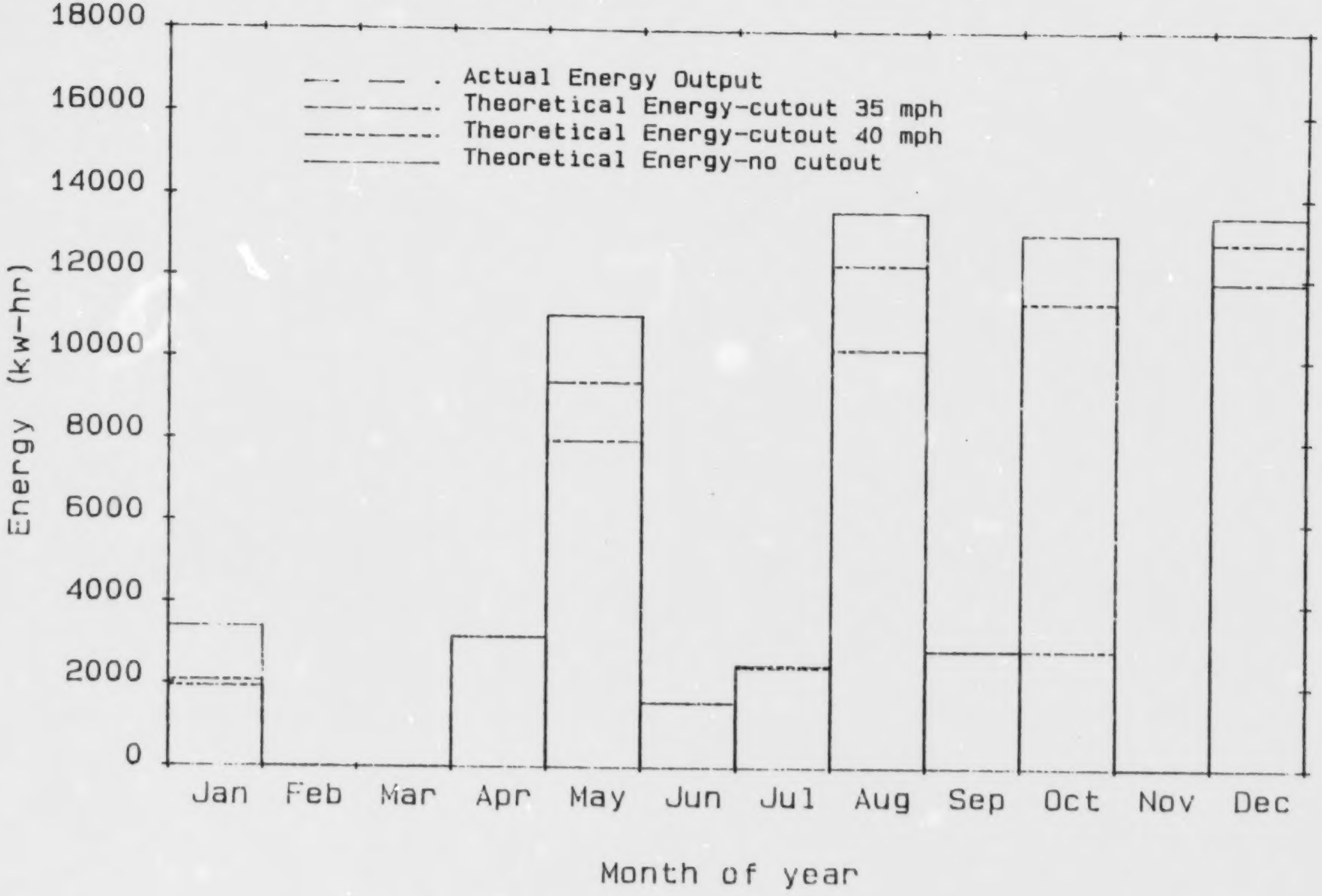
BETZ LIMIT KW-HR

RANKIN INLET 1986



TURBINE THEORETICAL ENERGY KW-HR

RANKIN INLET 1986



Site Log: Rankin Inlet

Mar. 1985	The site manager reports that the batteries are bad. New batteries were sent to the site.
Apr. 1985	The site manager informed TES that the wind histogram recorder had failed. Replacement equipment was sent out to the site.
June 1985	The wind histogram recorder was restarted on May 30, 1985. Other new equipment was sent to the site in June.
Dec. 1985	All equipment appears to be functioning correctly.
Mar. 1986	The site inspector indicates that the anemometer and cups are still frozen, however, he expects them to be active fairly soon.
Apr. 1986	Site reactivated April 17, 1986.

Appendix D
Rattlesnake Hill

AIR DENSITY COMPENSATION FACTORS
BASED ON
A.E.S. NORMALS AT THE CLOSEST A.E.S. STATION

SITE: RATTLESNAKE HILL

ALTITUDE: 612 m CLOSEST A.E.S. STATION: Rattlesnake Hill

STD AIR PRESSURE: 94.31 kPa

	AVERAGE MONTHLY A.E.S. TEMPERATURE T_{avg} °K	COMPENSATION FACTOR f_{comp} $f_{Comp} = \frac{288.15}{T_{avg}} \times \frac{\text{Std Air Pressure}}{101.33}$
JANUARY	271.1	0.989
FEBRUARY	277.3	0.967
MARCH	283.2	0.947
APRIL	289.8	0.925
MAY	295.3	0.908
JUNE	298.6	0.898
JULY	302.6	0.886
AUGUST	301.3	0.890
SEPTEMBER	296.1	0.906
OCTOBER	287.7	0.932
NOVEMBER	278.7	0.962
DECEMBER	273.6	0.980

Notes: Compensated Energy Output = Estimated Energy Output x f_{comp}

A.E.S. data obtained from Canadian Climate Normals

Temperature 1951 - 1980 UDC: 551.582(71)

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL RATTLESNAKE HILL COMPENSATED

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.																		
FEB.																		
MAR.																		
APR.																		
MAY																		
JUNE																		
JULY																		
AUG.																		
SEP.*1	332.0	4.4	2.17	2536	61.8	538.1												538.3
OCT.	840.8	2.8	1.76	2286	38.7	294.2												294.2
NOV.	679.1	3.8	1.86	4282	88.2	883.9												885.7
DEC. *2	770.4	2.0	1.53	2000	38.1	363.8												364.4
SUM.	2622.3	3.0	1.71	11104	226.8	1196.1												1196.9

NOTES: Explanation on following page

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL RATTLESNAKE HILL

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.																		
FEB.																		
MAR.																		
APR.																		
MAY																		
JUNE																		
JULY																		
AUG.																		
SEP.*1	332.0	4.4	2.17	2536	61.8	593.9												594.1
OCT.	840.8	2.8	1.76	2286	38.7	315.6												315.6
NOV.	679.1	3.8	1.86	4282	88.2	918.8												920.7
DEC. *2	770.4	2.0	1.53	2000	38.1	371.2												371.8
SUM.	2622.3	3.0	1.71	11104	226.8	2199.5												2202.2

NOTES: Explanation on following page.

NOTES ON RATTLESNAKE HILL 1986

*1 Site operation started on September 11, 1986.

*2 Histogram recorder data short 2 days.

MONTHLY AVERAGE WIND SPEED AND WEIBULL PARAMETER "K" AS CALCULATED FROM CONTINUOUSLY RUNNING WIND HISTOGRAM RECORDER

SITE NAME: Rattlesnake Hill

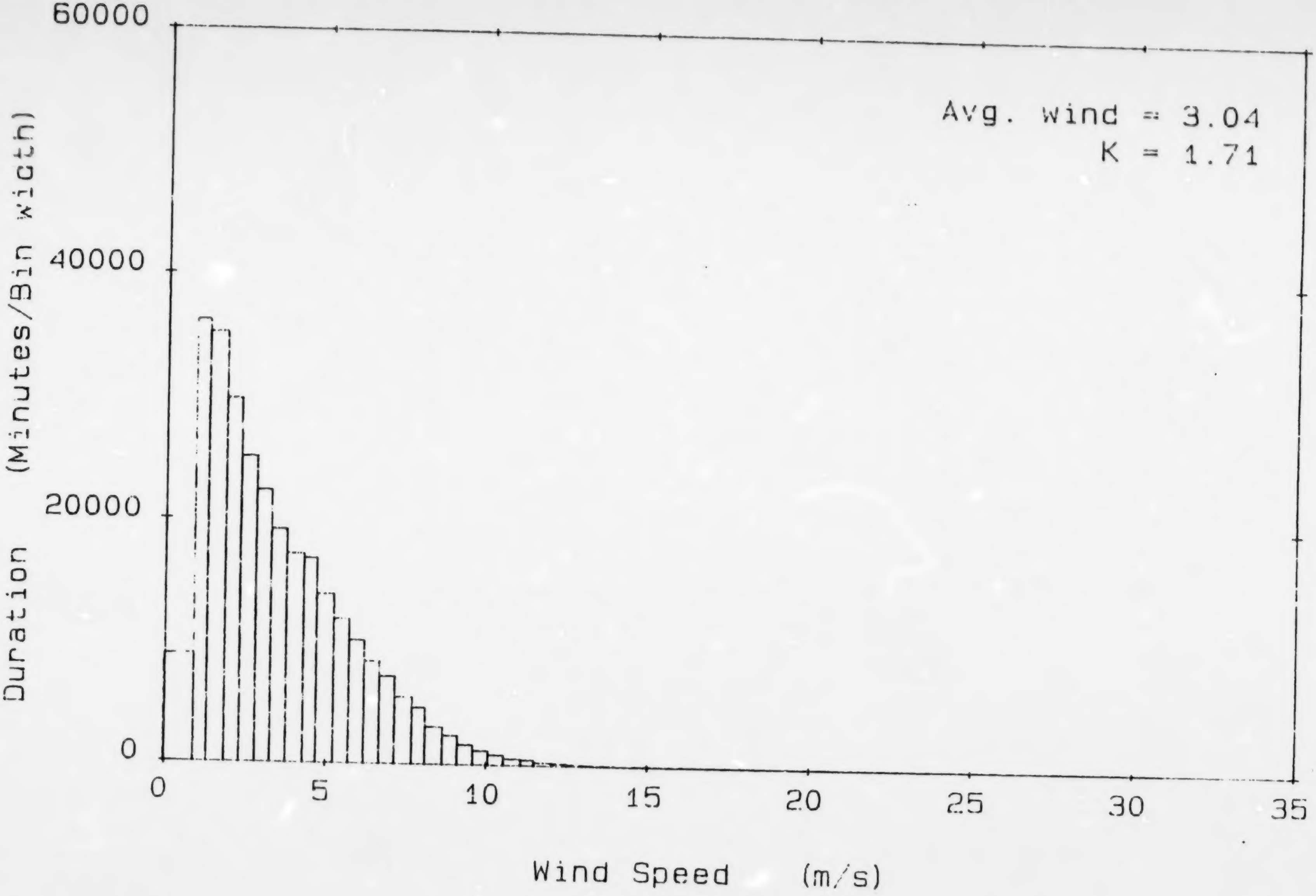
YEAR: 1986

APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January				
February				
March				
April				
May				
June				
July				
August				
September *1	332.0	4.4	2.17	0.031
October	840.8	2.8	1.76	0.120
November	679.1	3.8	1.86	0.063
December	770.4	2.0	1.53	0.175
YEAR	2622.3	3.0	1.71	0.103

Notes: *1 Site operation started on September 11, 1986.

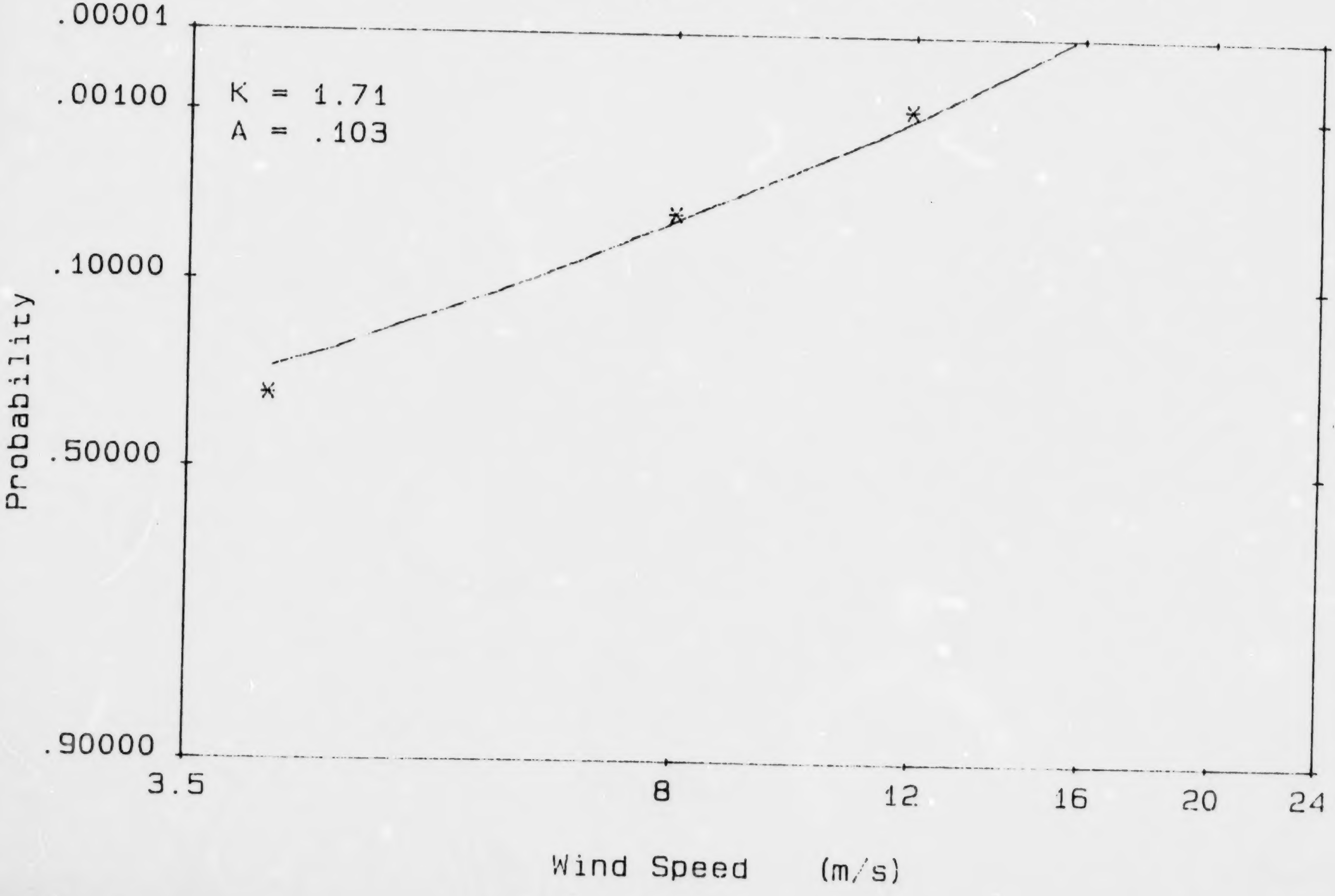
RATTLESNAKE HILL

September 11 1986 to December 31 1986



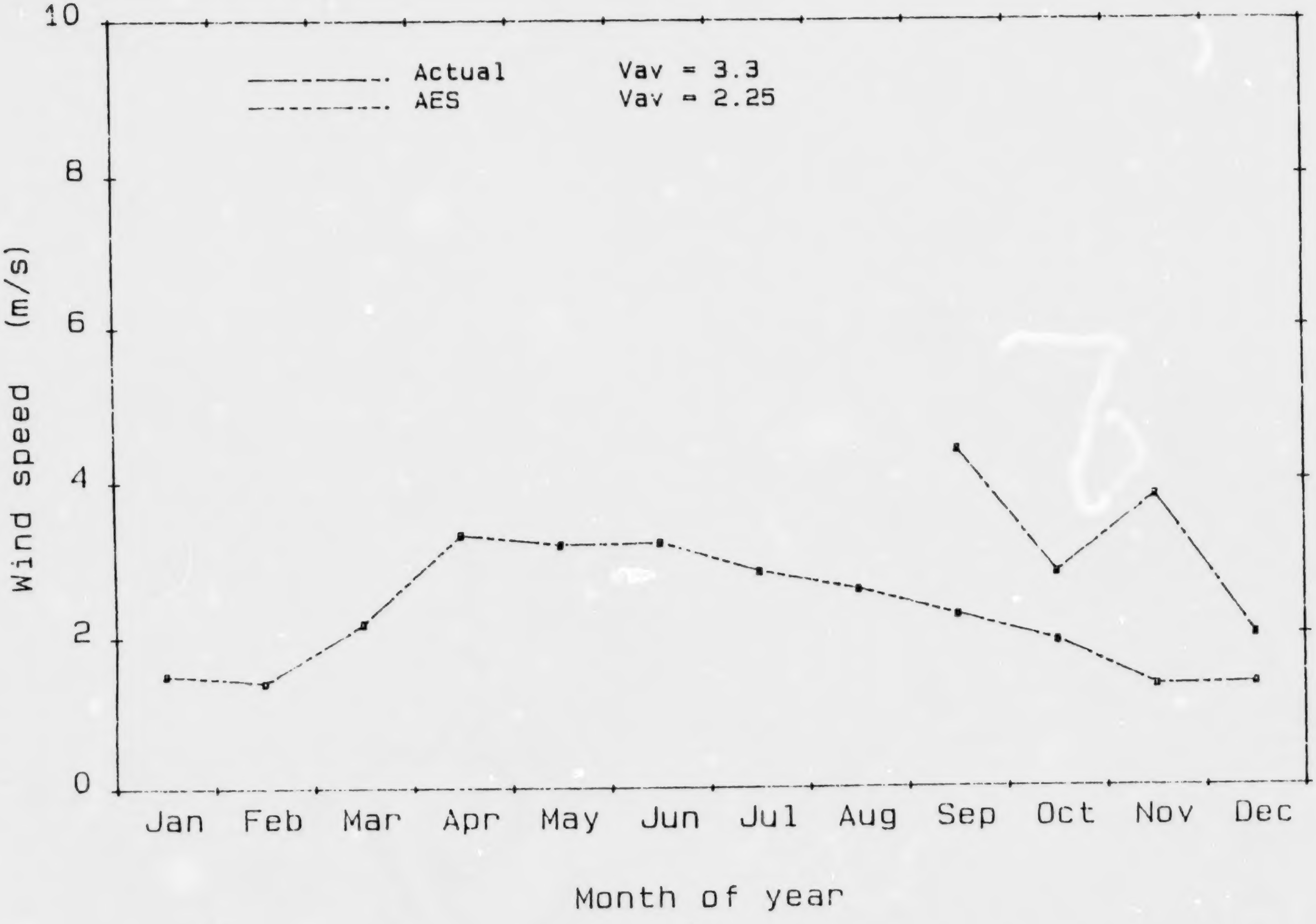
RATTLESNAKE HILL

September 11 1986 to December 31 1986



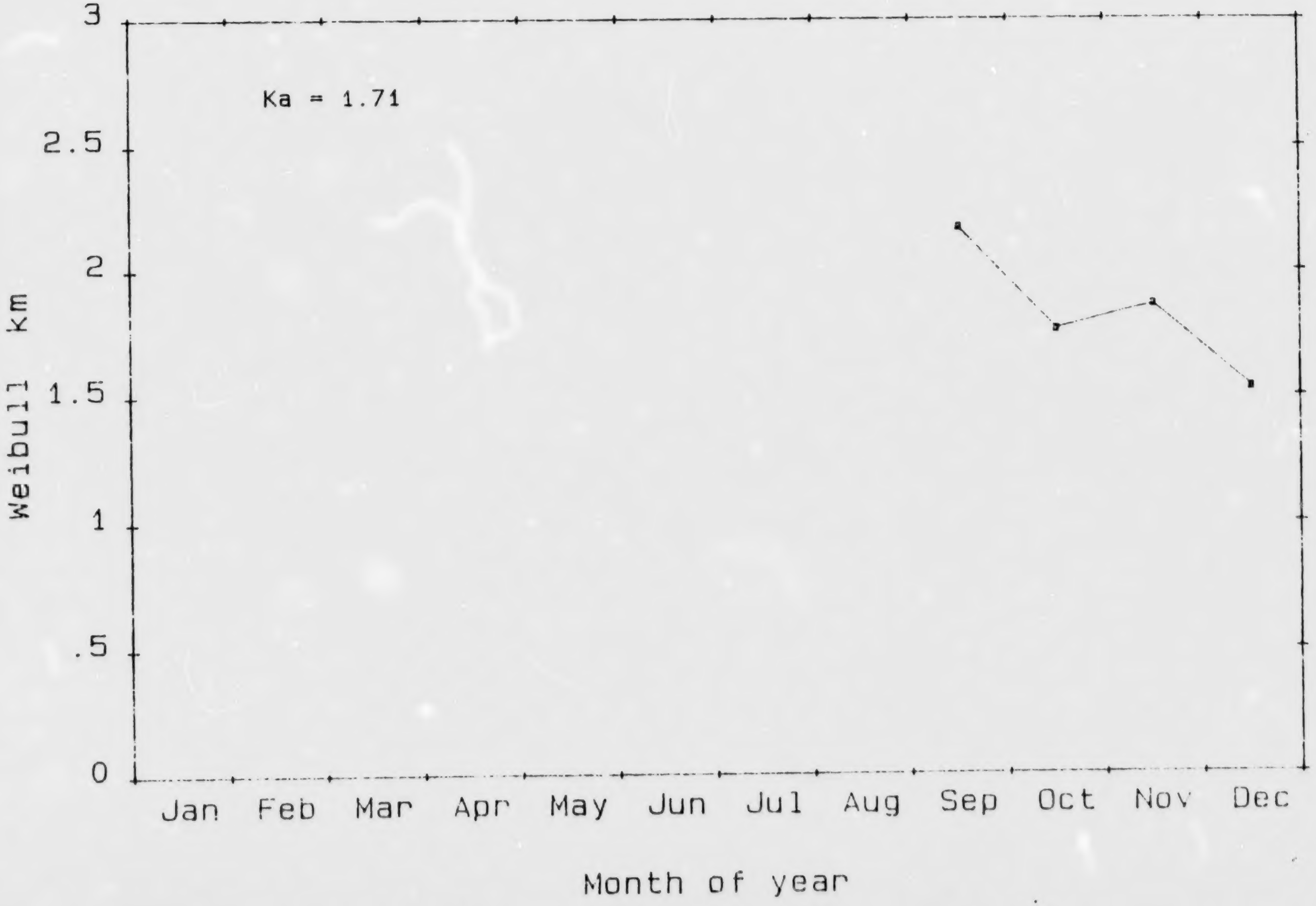
COMPARISON OF AVERAGE WIND SPEEDS

RATTLESNAKE HILL 1986



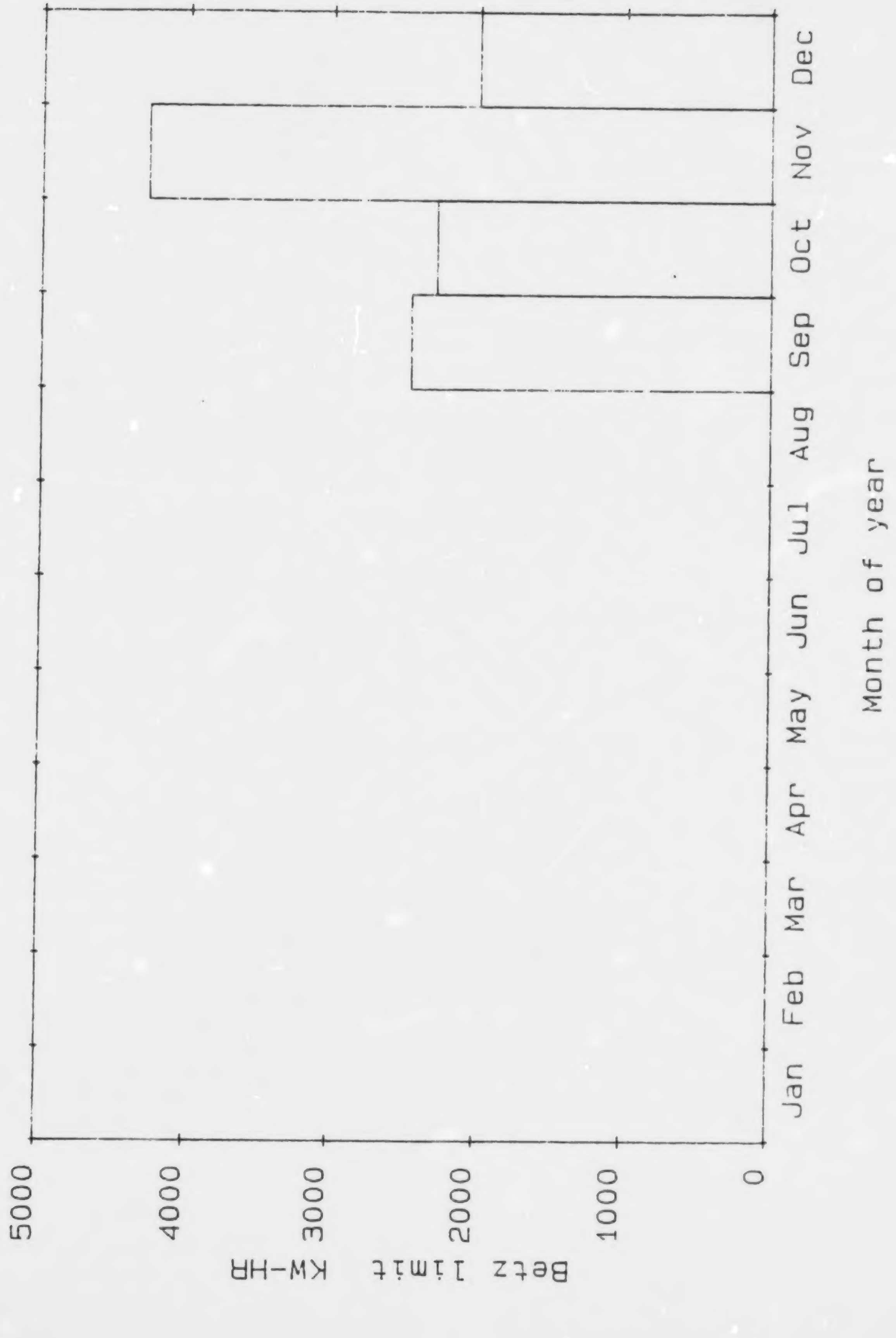
WEIBULL PARAMETER km VS month

RATTLESNAKE HILL 1986



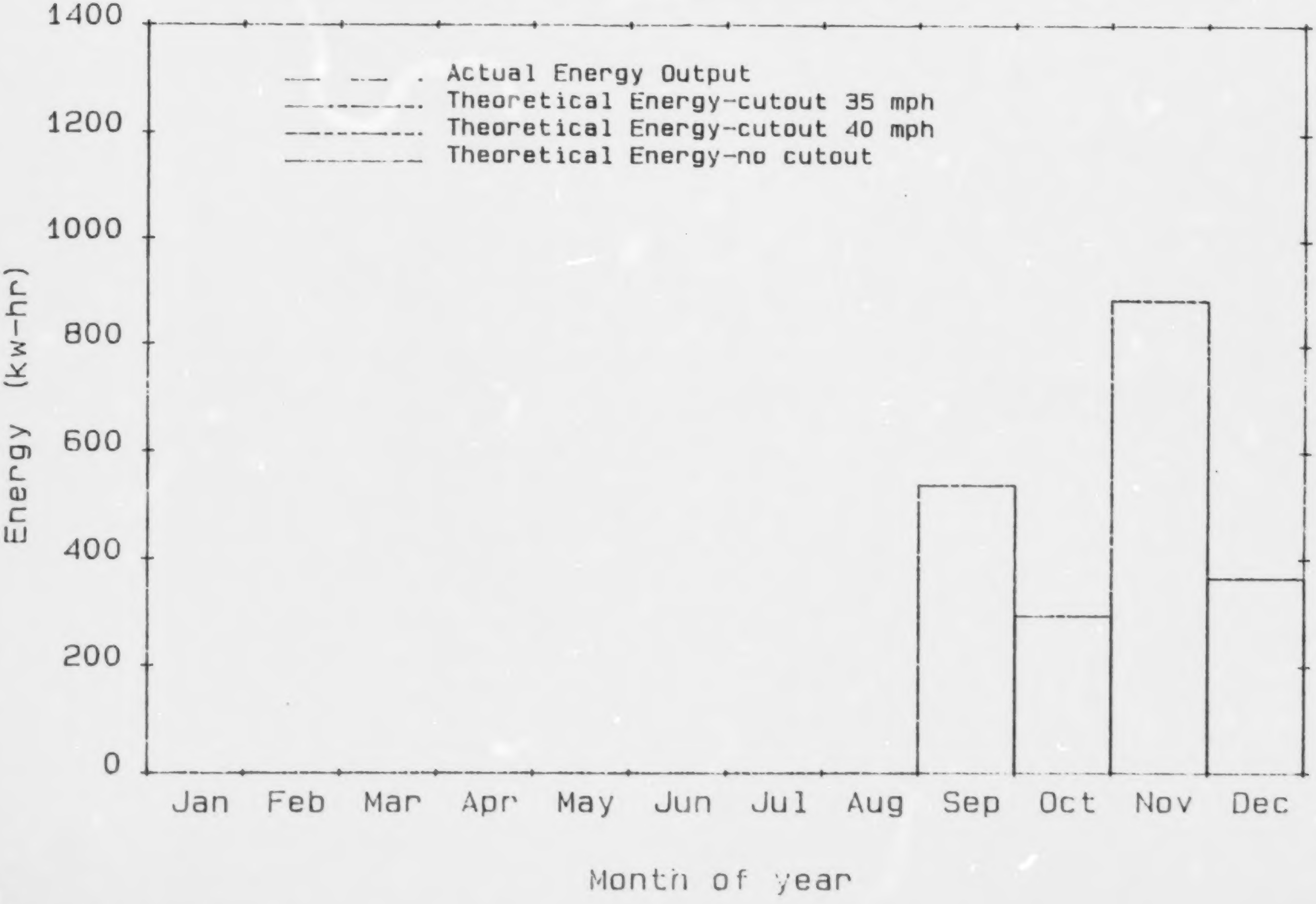
BETZ LIMIT KW-HR

RATTLESNAKE HILL 1986



TURBINE THEORETICAL ENERGY KW-HR

RATTLESNAKE HILL 1986



Site Log: Rattlesnake Hill

Sep. 1986 The site is now operational. Photographs and topographic maps of the area have been received from the site staff. The site is part of a photo-voltaic pumping demonstration program. The tower is erected on a plateau on the north slope of a hill. The land around the tower is flat and treeless. The land in the distance is mountainous and suggests that the site is centred on a smaller hill in a broad mountain valley.

Appendix E
St Anthony

AIR DENSITY COMPENSATION FACTORS
BASED ON
A.E.S. NORMALS AT THE CLOSEST A.E.S. STATION

SITE: ST. ANTHONY

ALTITUDE: 15m CLOSEST A.E.S. STATION: St. Anthony 'A' Nfld.

STD AIR PRESSURE: 99.13 kPa

	AVERAGE MONTHLY A.E.S. TEMPERATURE T_{avg} ^{o}K	COMPENSATION FACTOR f_{comp} $f_{Comp} = \frac{288.15}{T_{avg}} \times \frac{\text{Std Air Pressure}}{101.33}$
JANUARY	263.1	1.07
FEBRUARY	263.4	1.07
MARCH	267.1	1.06
APRIL	271.1	1.04
MAY	275.9	1.02
JUNE	281.0	1.00
JULY	296.0	0.95
AUGUST	285.6	0.99
SEPTEMBER	281.3	1.00
OCTOBER	276.6	1.02
NOVEMBER	272.1	1.04
DECEMBER	266.5	1.06

Notes: Compensated Energy Output = Estimated Energy Output x f_{comp}

A.E.S. data obtained from Canadian Climate Normals
Temperature 1951 - 1980 UDC: 551.582(71)

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL ST. ANTHONY COMPENSATED

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① PROX. NTH : CORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
AN.																		
EB.																		
AR.	702.6	8.5	2.24	37891	424.2	10223.0												11864.2
PR.	767.4	6.2	1.68	19950	272.5	5192.6												5881.2
AY	696.9	7.6	2.25	25142	372.5	8051.4												8517.8
UNE	722.8	8.5	2.33	32803	456.4	9662.2												10730.6
ULY *1																		
UG. *2																		
EP.	618.6	8.8	2.99	27416	420.1	8043.8												8881.4
CT.	771.5	7.0	1.54	28350	301.8	4929.2												6930.6
OV.	697.4	9.6	2.06	53917	383.9	9065.8												12976.4
EC.	747.3	9.3	2.23	50125	437.7	10377.8												13499.2
UM.	5724.5	8.1	2.0	275594	3069.1	65545.8												79281.4

NOTES: Explanation of following pages.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL ST. ANTHONY

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① PROX. NTH CORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
AN.																		
EB.																		
AR.	702.6	8.5	2.24	37891	424.2	9644.3												11192.6
PR.	767.4	6.2	1.68	19950	272.5	4992.9												5655.0
AY	696.9	7.6	2.25	25142	372.5	7893.5												8350.8
UNE	722.8	8.5	2.33	32803	456.4	9662.2												10730.6
ULY *1																		
UG. *2																		
EP.	618.6	8.8	2.99	27416	420.1	8043.8												8881.4
CT.	771.5	7.0	1.54	28350	301.8	4832.5												6794.7
OV.	697.4	9.6	2.06	53917	383.9	8717.1												12477.3
EC.	747.3	9.3	2.23	50125	437.7	9790.4												12735.1
UM.	5724.5	8.1	2.0	275594	3069.1	63576.7												76817.5

OTES: Explanation on following page.

NOTES ON ST. ANTHONY 1986

*1 Site is operational, but data appeared highly unusual and contained 140 hours of counts in excess of the calendar month (18% over).

*2 The WHR was not operating when read, hydro staff have since confirmed correct operation.

MONTHLY AVERAGE WIND SPEED
AND WEIBULL PARAMETER "K"
AS CALCULATED FROM CONTINUOUSLY
RUNNING WIND HISTOGRAM RECORDER

SITE NAME: ST. ANTHONY

YEAR: 1986

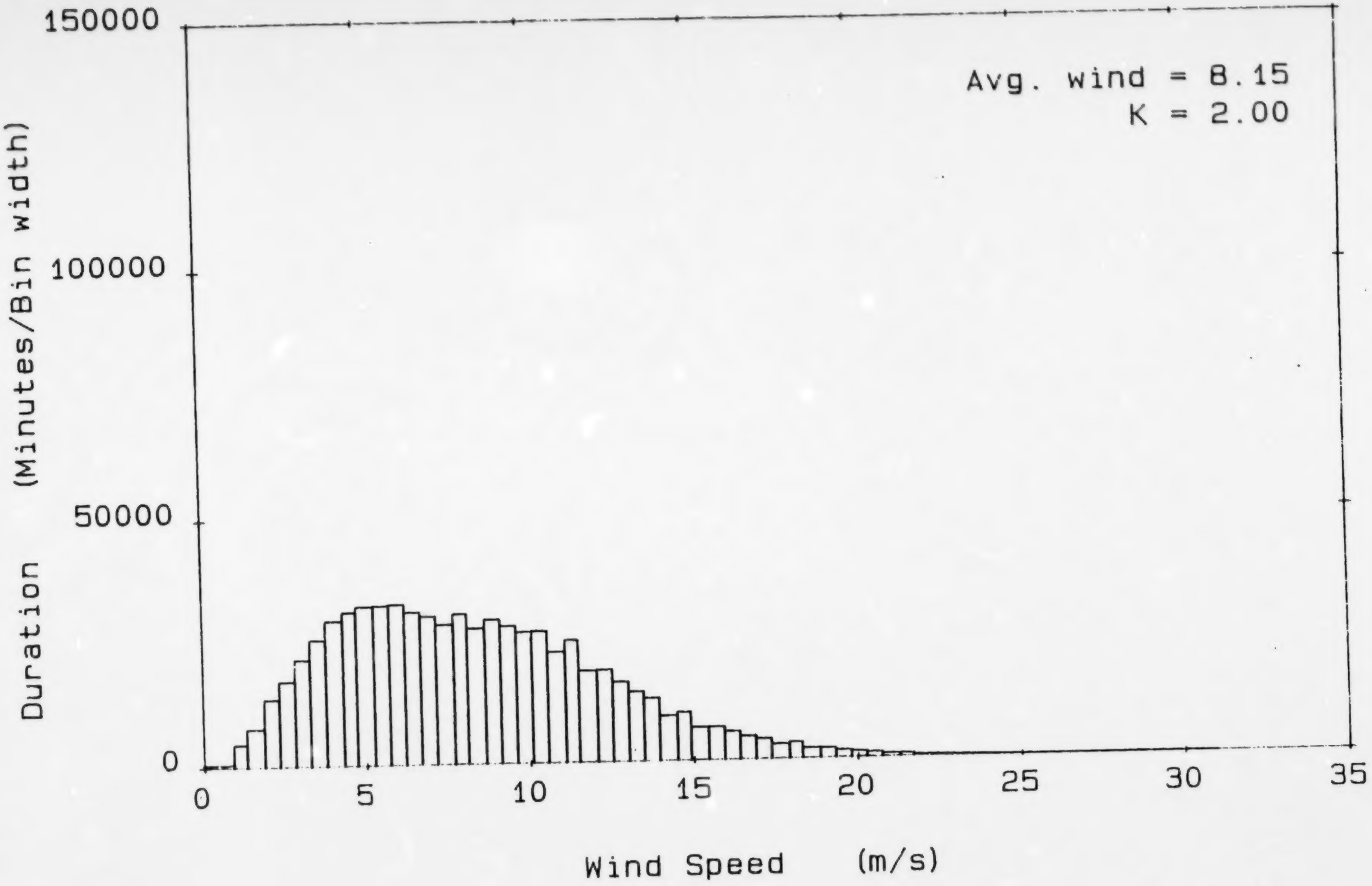
APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January				
February				
March	702.6	8.5	2.24	0.006
April	767.4	6.2	1.68	0.041
May	696.9	7.6	2.25	0.009
June	722.8	8.5	2.33	0.006
July *1				
August *2				
September	618.6	8.8	2.99	0.001
October	771.5	7.0	1.54	0.046
November	697.4	9.6	2.06	0.008
December*3	747.3	9.3	2.0	0.006
YEAR *3	5724.5	8.1	2.0	0.013

Notes:

*1 Site is operational, but data appeared highly unusual.

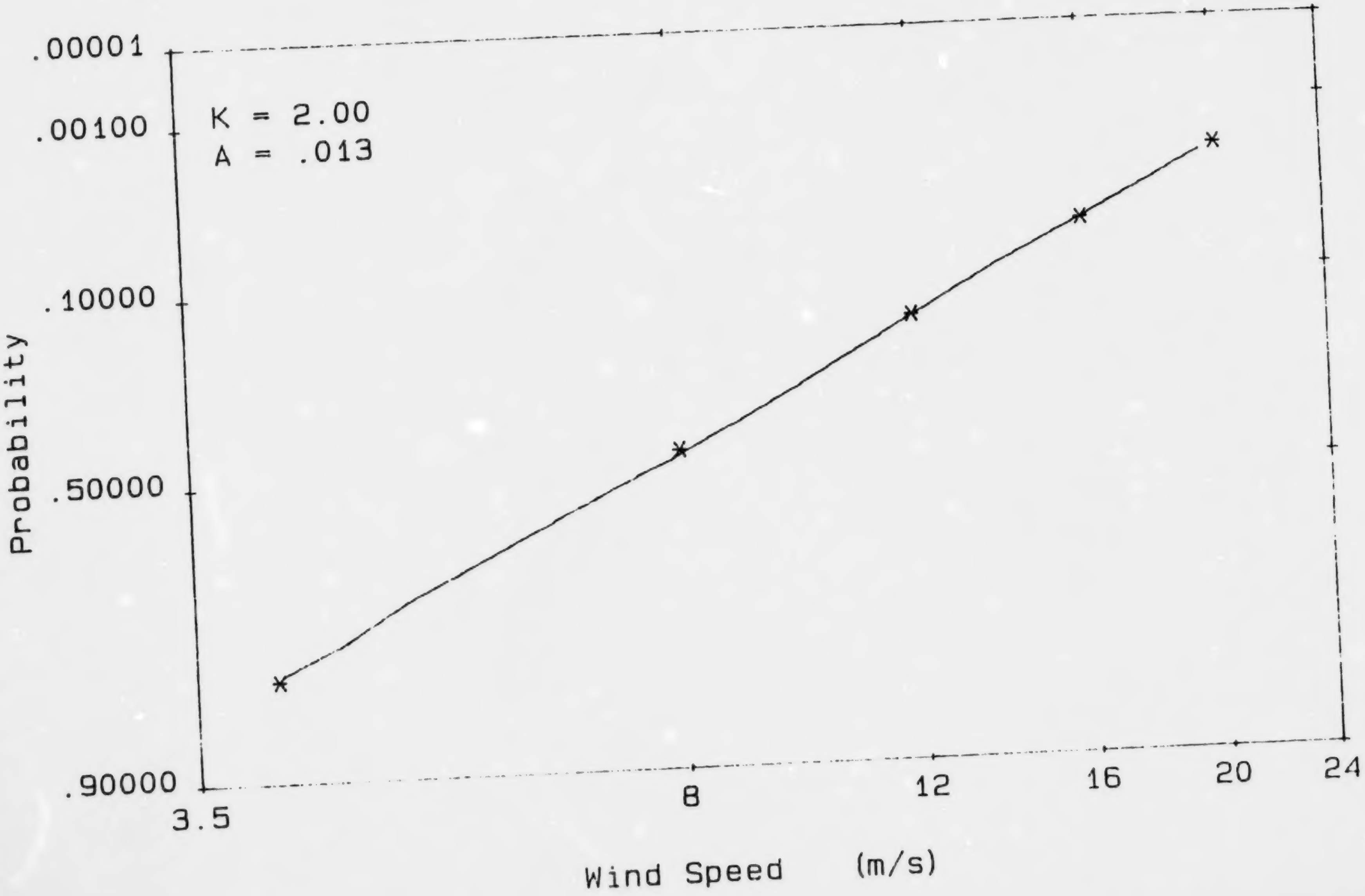
*2 The WHR was not operating when read, hydro staff have since confirmed correct operation.

*3 Period March 5, 1986 through January 1, 1987
Period July 2, 1986 through September 04, 1986 not reported.



ST-ANTHONY

March 5 1986 to January 1 1987

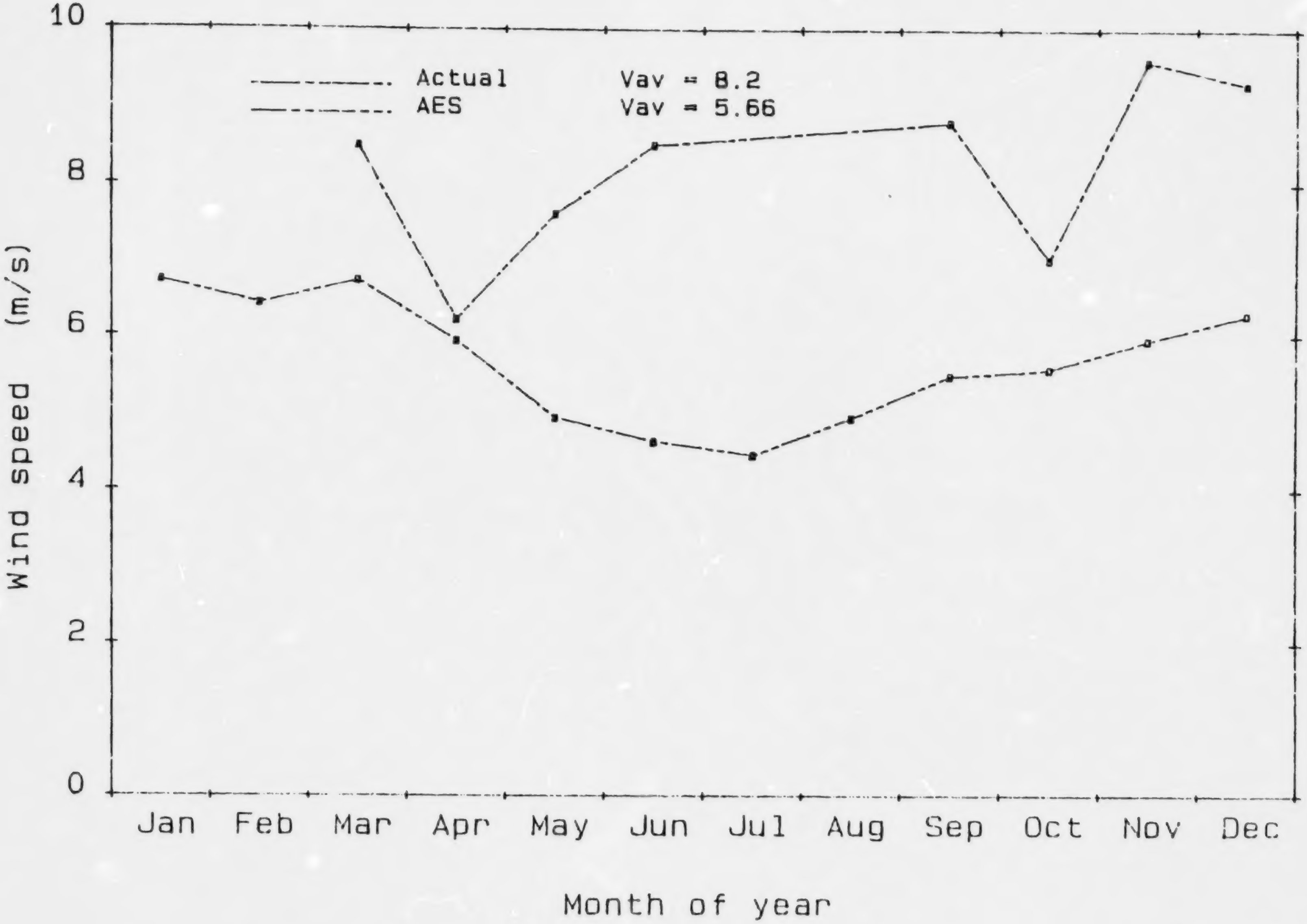


ST-ANTHONY

March 5 1986 to January 1 1987

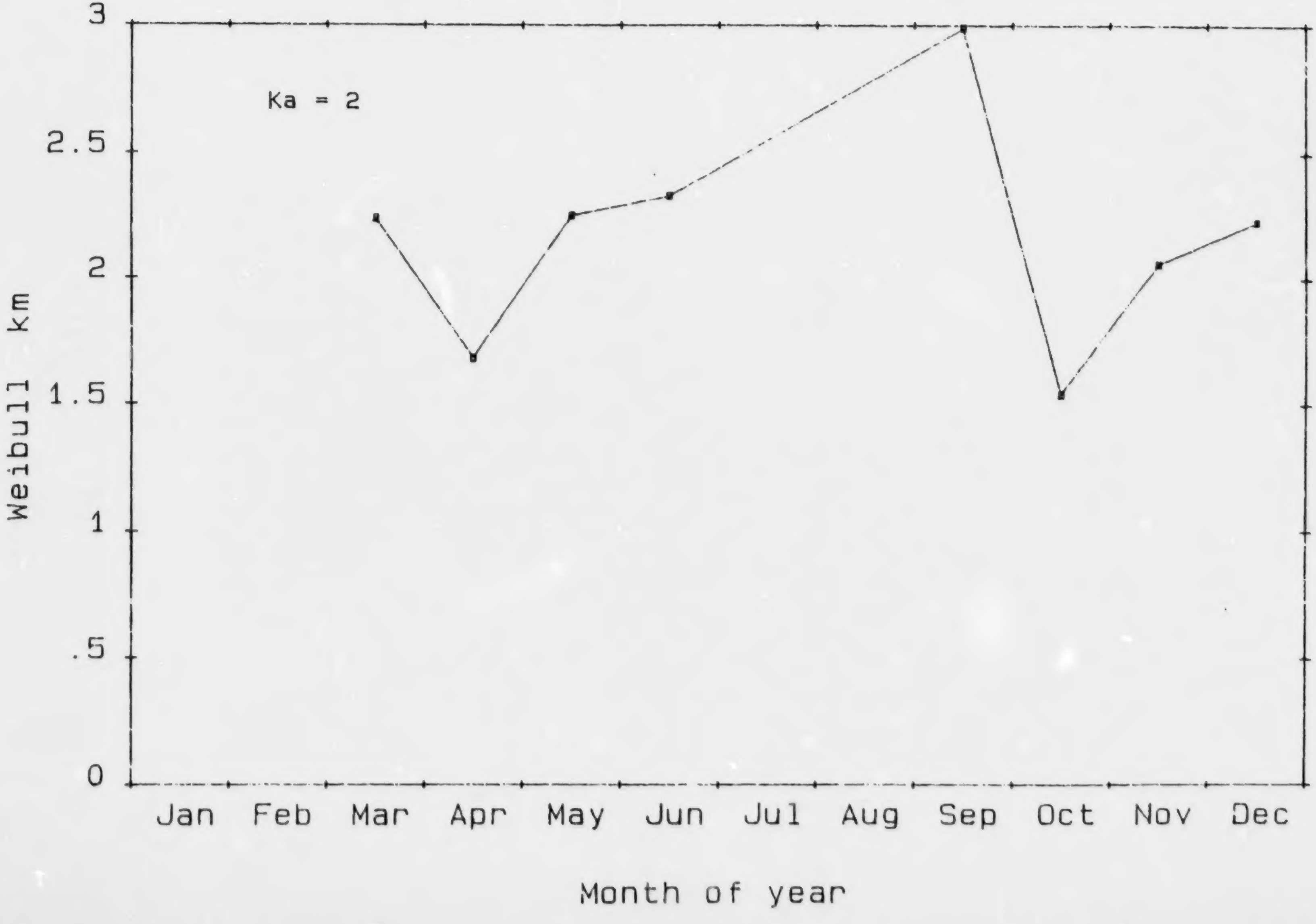
COMPARISON OF AVERAGE WIND SPEEDS

ST. ANTHONY 1986



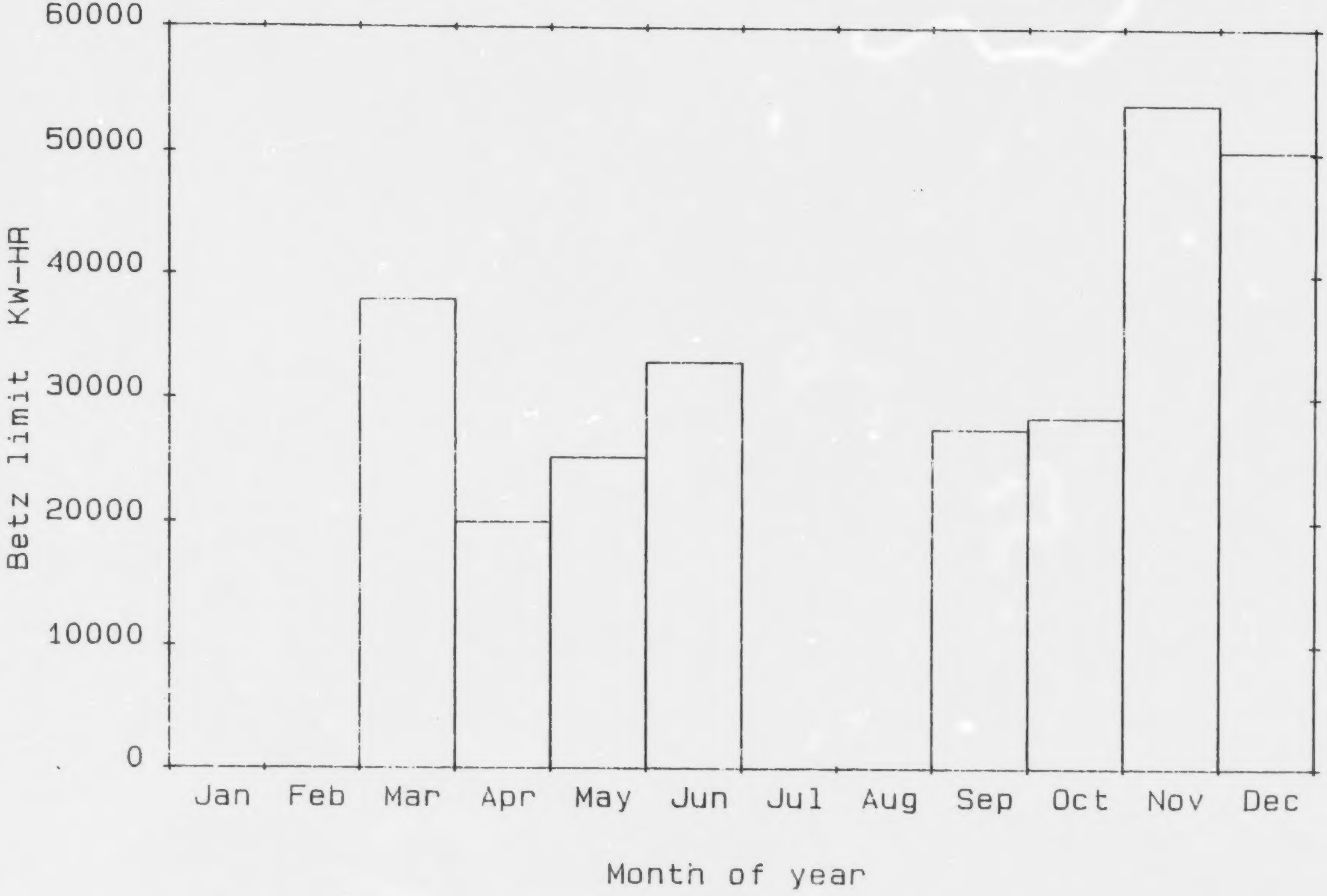
WEIBULL PARAMETER km VS month

ST. ANTHONY 1986



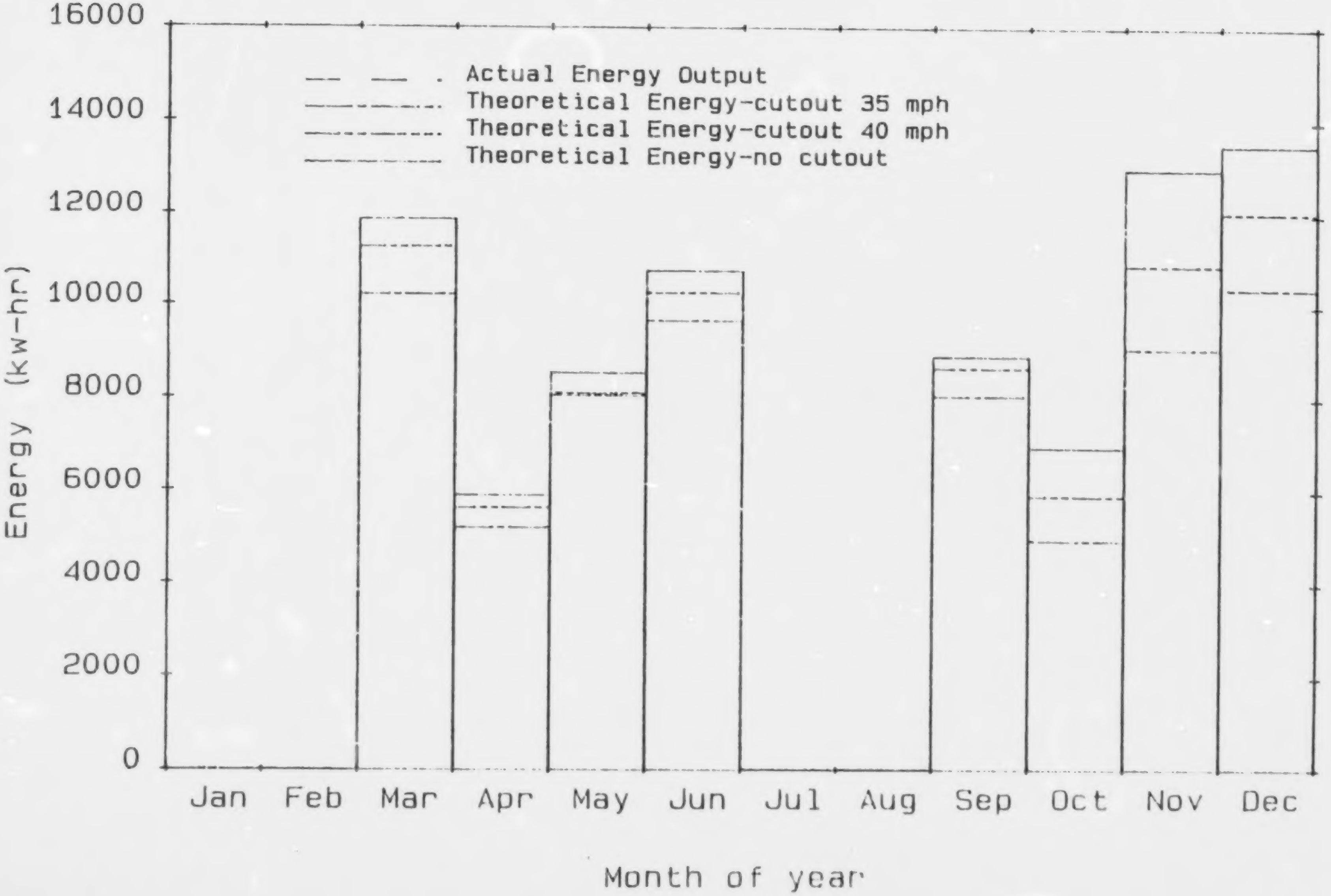
BETZ LIMIT KW-HR

ST. ANTHONY 1986



TURBINE THEORETICAL ENERGY KW-HR

ST. ANTHONY 1986



Site Log: St. Anthony

Mar. 1986	The site is now operational. It is located at a light-house in what is considered to be a very windy area. Calm periods are rare and both consistent and stormy wind conditions should be expected.
Aug. 1986	The WHR failed and was repaired by Hydro staff using parts from a second available WHR.

Appendix F
Sainte Anne University

AIR DENSITY COMPENSATION FACTORS
BASED ON
A.E.S. NORMALS AT THE CLOSEST A.E.S. STATION

SITE: St. Anne University

ALTITUDE: 17m CLOSEST A.E.S. STATION: Weymouth (Falls) N.S.

STD AIR PRESSURE: 101.13 kPa

	AVERAGE MONTHLY A.E.S. TEMPERATURE T_{avg} °K	COMPENSATION FACTOR f_{comp} $f_{Comp} = \frac{288.15}{T_{avg}} \times \frac{\text{Std Air Pressure}}{101.33}$
JANUARY	269.8	1.07
FEBRUARY	269.1	1.07
MARCH	273.1	1.05
APRIL	278.0	1.03
MAY	283.5	1.01
JUNE	288.1	1.00
JULY	291.3	0.99
AUGUST	290.7	0.99
SEPTEMBER	287.1	1.00
OCTOBER	282.5	1.02
NOVEMBER	278.1	1.03
DECEMBER	272.1	1.06

Notes: Compensated Energy Output = Estimated Energy Output x f_{comp}

A.E.S. data obtained from Canadian Climate Normals
Temperature 1951 - 1980 UDC: 551.582(71)

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL UNIVERSITE SAINTE ANNE COMPENSATED

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① PROX. NTH CORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
AN.																		
EB.																		
AR.																		
PR.																		
AY																		
UNE *1																		
ULY *2																		
UG. *3																		
EP.	532.7	5.1	1.99	6834	134.8	2152.0												2166.1
CT.	761.8	5.4	1.79	10937	216.9	3125.3												3242.4
OV.	721.7	6.7	1.82	21391	303.7	6245.6												6872.7
EC.	742.6	7.5	2.07	27745	389.9	8454.7												9243.8
UM.	2758.8	5.6	1.69	66907	1045.3	19977.6												21525

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL UNIVERSITE SAINTE ANNE

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① PROX. NTH CORD	② TOTAL TIME IN PERIOD	③ AVERAGE WIND SPEED	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT	⑥ EST. GEN. TIME	⑦ EST. OUTPUT ENERGY	⑧ DOWN TIME	⑨ STOP TIME	⑩ IDLE TIME	⑪ ACTUAL GEN. TIME	⑫ ACTUAL INPUT ENERGY	⑬ ACTUAL OUTPUT ENERGY	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME)	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED
	h	m/s		kWh	h	kWh	h	h	h	h	kWh	kWh	kWh	%	%	%	%	kWh
AN.																		
EB.																		
AR.																		
PR.																		
AY																		
JNE *1																		
JLY *2																		
JG. *3																		2166.1
EP.	532.7	5.1	1.99	6834	134.8	2152.0												3178.8
CT.	761.8	5.4	1.79	10937	216.9	3064.0												6672.5
OV.	721.7	6.7	1.82	21391	303.7	6063.7												8720.6
EC.	742.6	7.5	2.07	27745	389.9	7976.1												
UM.	2758.8	5.6	1.69	66907	1045.3	19255.8												20738.0

OTES: Explanation on following page.

NOTES ON UNIVERSITE STE ANNE 1986

*1 Weekly data sheets have been received and processed. The analysis shows both an unusual wind histogram and a 40 - 50% error in the reporting period interval.

Equipment operation and correct operating procedure have been confirmed with the site manager. On-site tests by his staff are proceeding, and any suspect equipment will be replaced.

*2 Data not returned because only 10 hours were accumulated in a 168 hour period. New anemometer operating correctly, a new wind histogram recorder will be sent.

*3 Site now operating with new WHR. Data will be reported next month.

MONTHLY AVERAGE WIND SPEED AND WEIBULL PARAMETER "K" AS CALCULATED FROM CONTINUOUSLY RUNNING WIND HISTOGRAM RECORDER

SITE NAME: SAINTE ANNE UNIVERSITE

YEAR: 1986

APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January				
February				
March				
April				
May				
June *1				
July *2				
August *3				
September	532.7	5.1	1.99	0.033
October	761.8	5.4	1.79	0.044
November	721.7	6.7	1.82	0.028
December	742.6	7.5	2.07	0.013
YEAR	2758.8	5.6	1.69	0.048

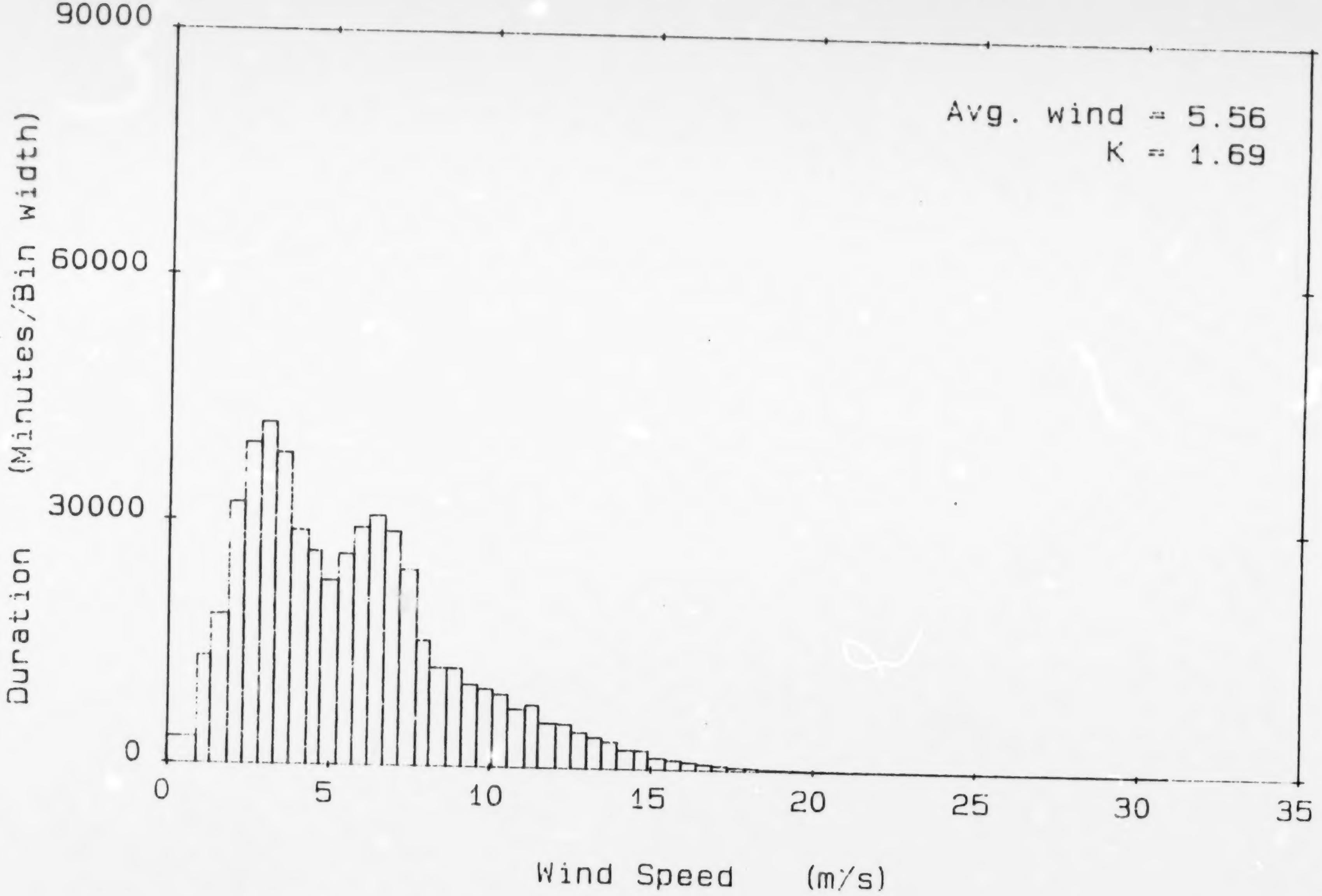
Notes: *1 Site is now operational, but data is not consistent with reporting period.

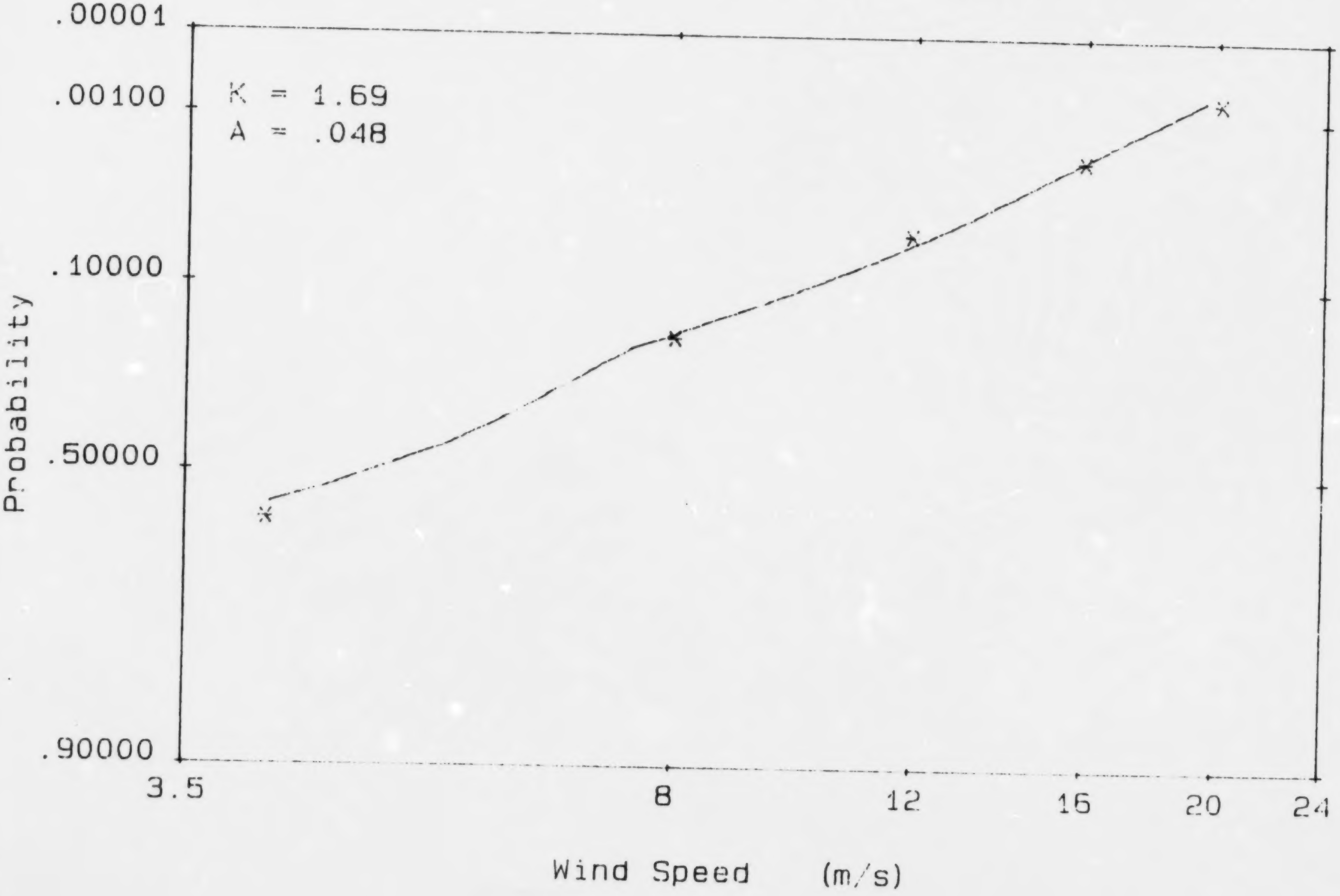
*2 Very little data recorded, wind histogram recorder and anemometer to be replaced.

*3 Site now operating with new WHR. Data will be reported next month.

UNIVERSITE SAINTE ANNE

June 25 1986 to January 1 1987



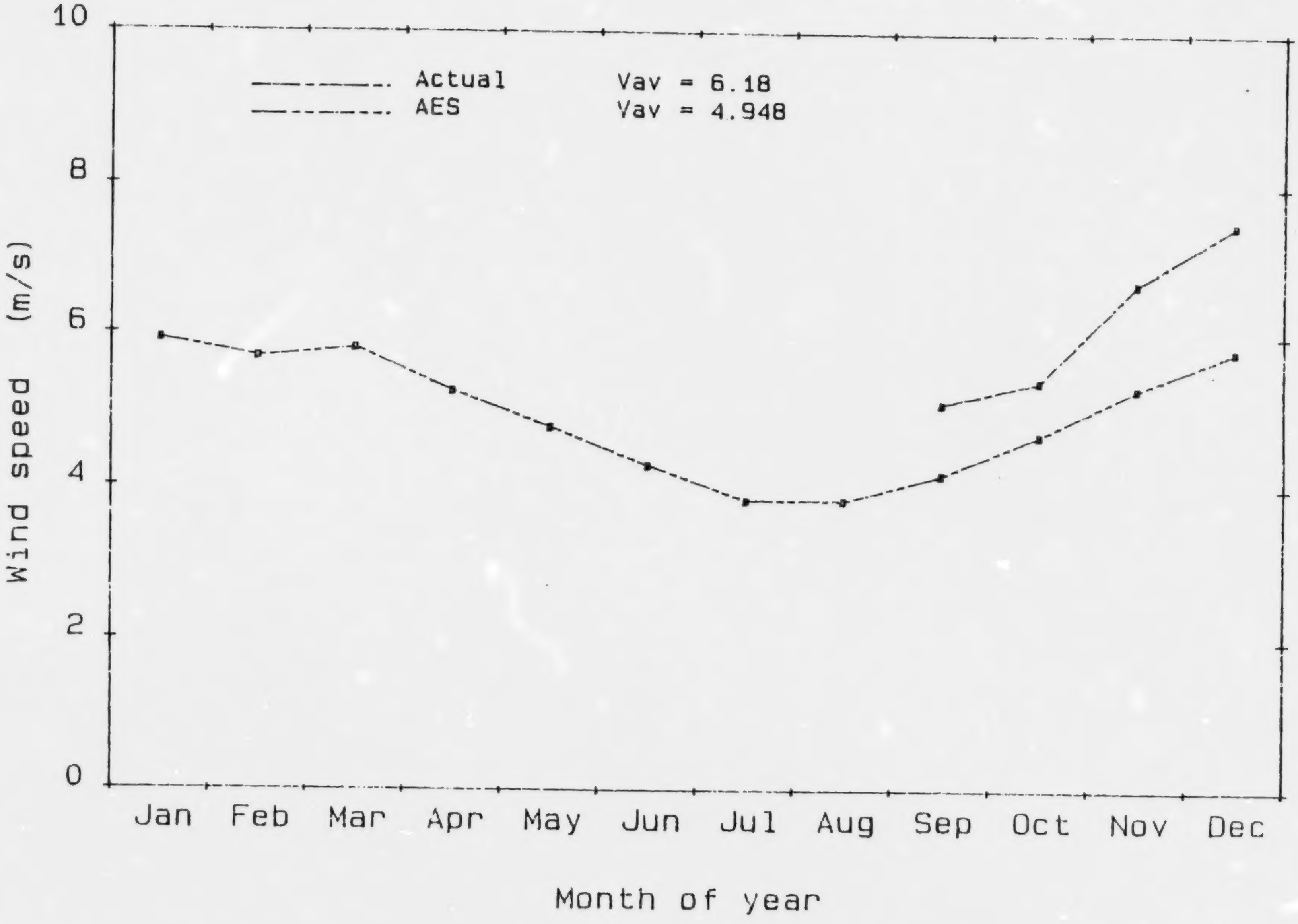


UNIVERSITE SAINTE ANNE

June 25 1986 to January 1 1987

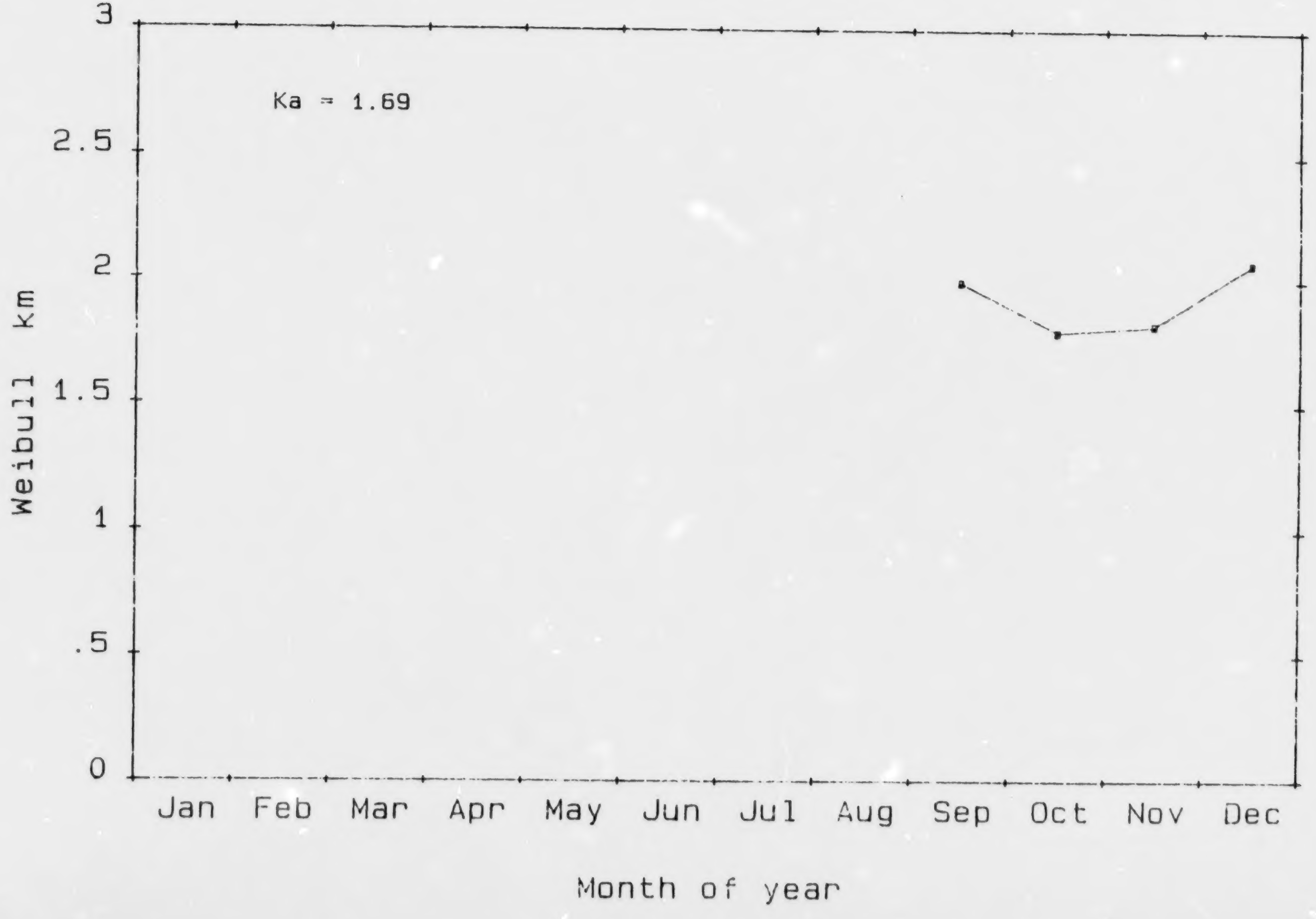
COMPARISON OF AVERAGE WIND SPEEDS

ST. ANNE UNIVERSITY 1986



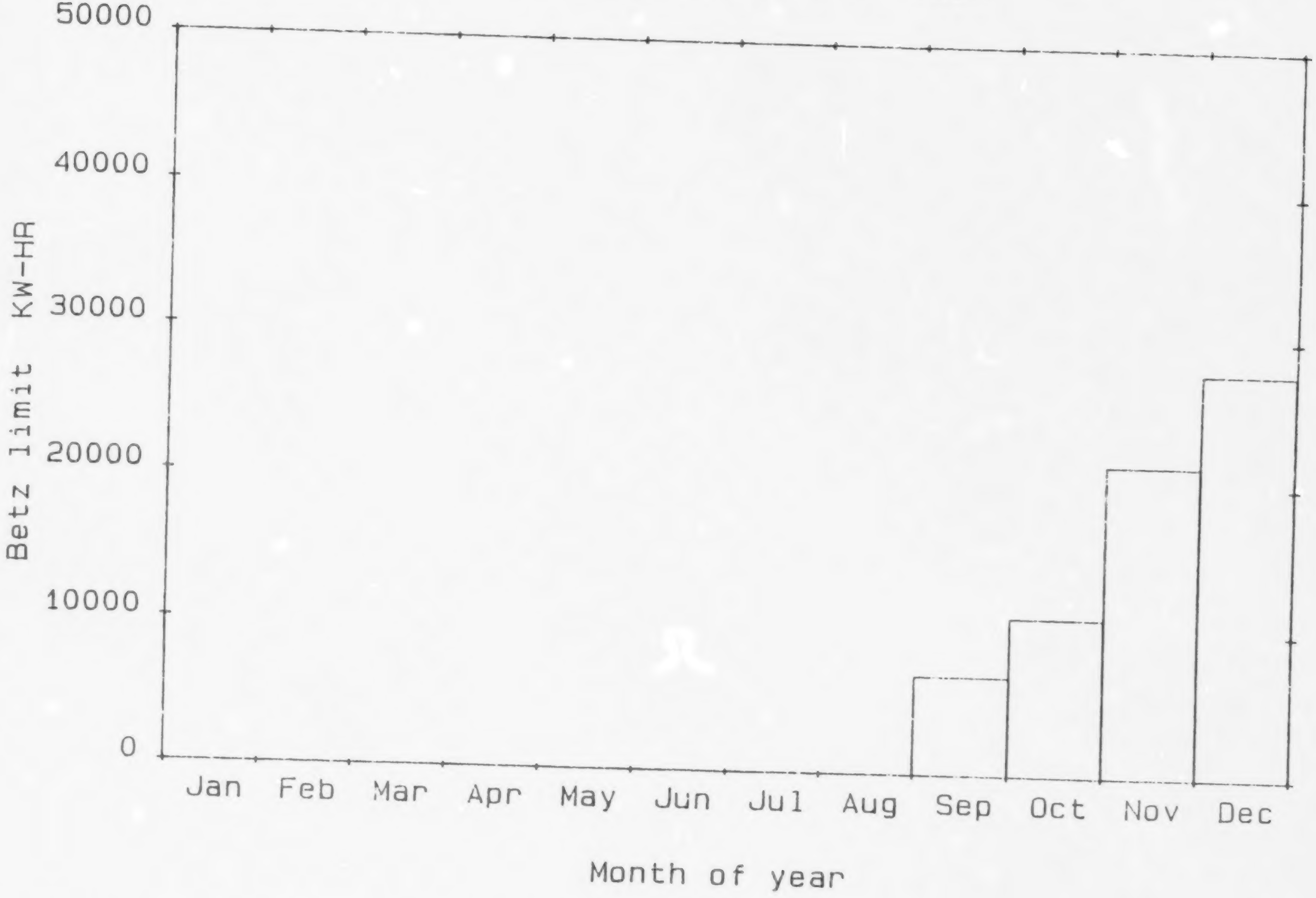
WEIBULL PARAMETER km VS month

ST. ANNE UNIVERSITY 1986



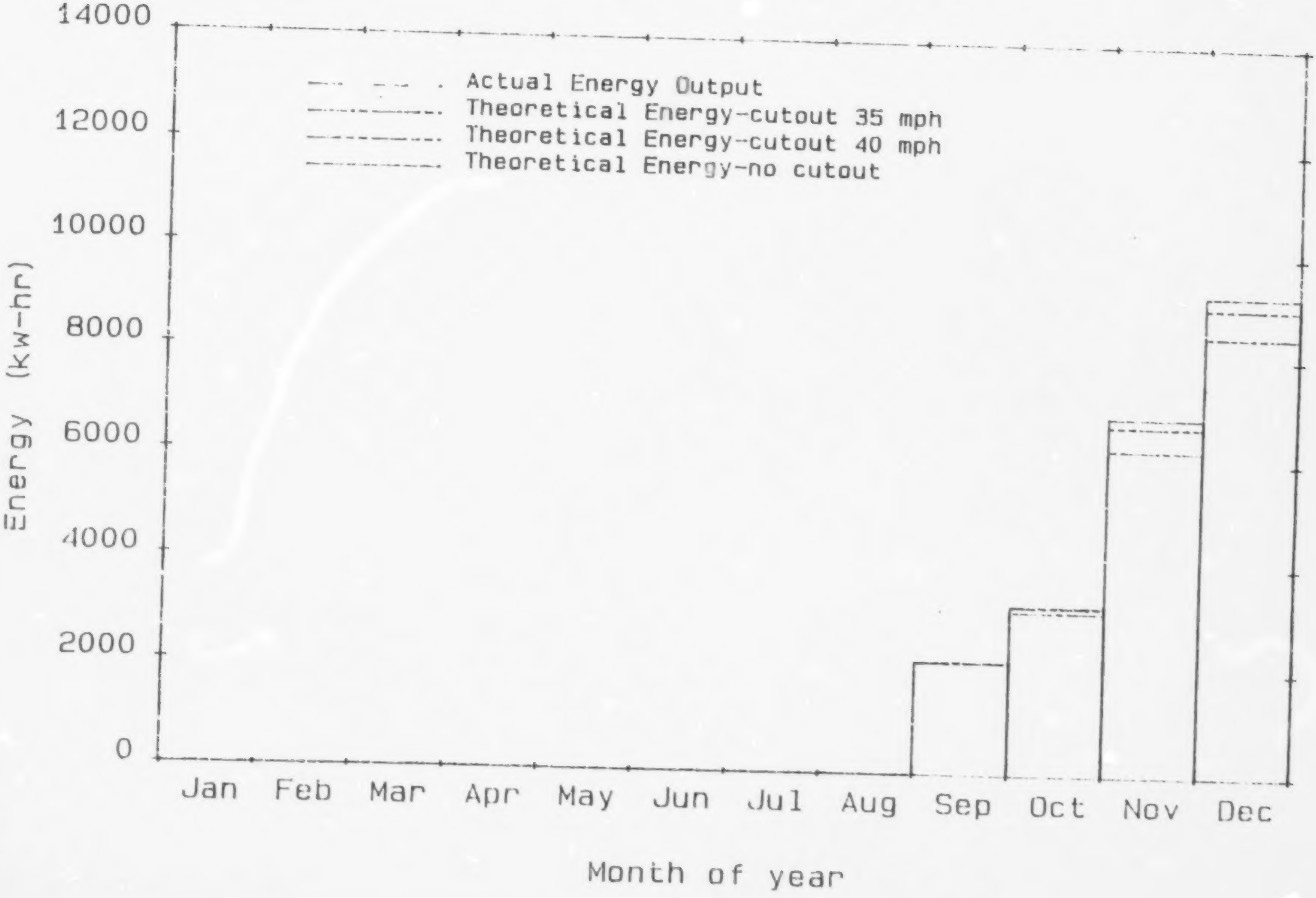
BETZ LIMIT KW-HR

ST. ANNE UNIVERSITY 1986



TURBINE THEORETICAL ENERGY KW-HR

ST. ANNE UNIVERSITY 1986



Site Log: Universite Sainte Anne

Jun. 1986	The site is now operational. It has been erected on the west coast of Nova Scotia at Pointe d'Eglise within ten miles of the Weymouth Falls AES station.
Aug. 1986	Data is now being reported after some difficulties and the replacement of the anemometer, cable and WHR.

Appendix G

Swift Current

AIR DENSITY COMPENSATION FACTORS
BASED ON
A.E.S. NORMALS AT THE CLOSEST A.E.S. STATION

SITE: Swift Current

ALTITUDE: 817 m CLOSEST A.E.S. STATION: Swift Current

STD AIR PRESSURE: 91.89 kPa

	AVERAGE MONTHLY A.E.S. TEMPERATURE T_{avg} °K	COMPENSATION FACTOR f_{comp} $f_{comp} = \frac{288.15}{T_{avg}} \times \frac{\text{Std Air Pressure}}{91.89}$
JANUARY	258.3	1.116
FEBRUARY	262.7	1.097
MARCH	267.3	1.078
APRIL	276.5	1.042
MAY	283.5	1.016
JUNE	288.1	1.000
JULY	291.3	0.989
AUGUST	290.5	0.992
SEPTEMBER	284.7	1.012
OCTOBER	278.8	1.034
NOVEMBER	269.3	1.070
DECEMBER	263.1	1.095

Notes: Compensated Energy Output = Estimated Energy Output x f_{comp}

A.E.S. data obtained from Canadian Climate Normals

Temperature 1951 - 1980 UDC: 551.582(71)

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL SWIFT CURRENT 64 BIN

CUT IN WIND SPEED 6.60 m/s
CUT OUT WIND SPEED 15.65 m/s

YEAR: 1981				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD HR	AVERAGE WIND SPEED M/S	K	AVAIL. WIND ENERGY BETZ LIMIT KW-HR	EST. GEN. TIME HR	EST. OUTPUT ENERGY KW-HR	DOWN TIME HR	STOP TIME HR	IDLE TIME HR	ACTUAL GEN. TIME HR	ACTUAL INPUT ENERGY KW-HR	ACTUAL OUTPUT ENERGY KW-HR	ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA KW-HR	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY %	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME %	ACTUAL GEN. % OF EST. GEN. TIME %	DOWN TIME % OF TOTAL TIME PERIOD %	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED KW-HR
JAN.																		
FEB.																		
MAR.																		
APR.																		
MAY																		
JUNE	814	6.6	1.88	20539	383	4421	3	766	5	30.9	37.6	304	364	1.48	6.88	8.06	0.35	4813
JULY	398	6.7	2.07	9586	197	2273.7	0	376	5	16.6	12.8	118	155.3	1.24	5.19	8.46	0.01	2350.0
AUG.	636	5.4	1.95	8725	230	1965.2	1	628	2	4.6	37.6	5		0.06	0.25	1.98	0.23	1979.0
SEPT.	724	6.5	2.09	16633	349	3930.6	1	689	5	29.5	34.4	335		2.0	5.52	8.40	0.20	4149.2
OCT.	717	7.5	2.50	23573	438	5053.2	0	716	0	0.8	5.6	3		0.01	0.06	0.19	0.04	5866.9
NOV.	771	6.7	2.53	18308	423	4881.3	0	771	0	0	0	0		0	0	0	0	4942.3
DEC.	759	6.8	1.73	24123	348	4743.5	0	759	0	0	0	0		0	0	0	0	5570.3
SUM	4819	6.50	2.07	121487	2368	27268.5	5	4715	17	82.4	128.0	765	519.3	0.63	2.8	3.5	0.1	29670.7

NOTES: Explanation on following page.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL SWIFT CURRENT (Electronic A)

CUT IN WIND SPEED 6.60 m/s
OUT OUT WIND SPEED 15.65 m/s

YEAR: 1982				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE						ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME	ACTUAL GEN. % OF EST. GEN. TIME	DOWN TIME % OF TOTAL TIME PERIOD	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD HR	AVERAGE WIND SPEED M/S	K	AVAIL. WIND ENERGY BETZ LIMIT KW-HR.	EST. GEN. TIME HR	EST. OUTPUT ENERGY KW-HR	DOWN TIME HR	STOP TIME HR	IDLE TIME HR	ACTUAL GEN. TIME HR	ACTUAL INPUT ENERGY KW-HR	ACTUAL OUTPUT ENERGY KW-HR	KW-HR	%	%	%	%	KW-HR
JAN.	705.8	7.9	2.14	29877	413.5	6163.9	2	660	6.0	38.0	42.4	610	647.5	2.1	9.9	9.2	0.3	7288.7
FEB.	672.3	7.3	2.25	20812	371.5	5205.3	0	622	12.0	38.6	40.0	352	411.6	1.7	6.8	10.1	0	5536.8
MAR. *6	796.4	7.7	1.97	32728	408.0	6429.8	0	712.5	9.9	74.0	36,8	1036	365.4	3.2	16.1	18.1	0	7552.7
APR.	726.0	7.5	2.08	25714	391.4	5168.2	0	661.8	0	64.2	51.2	694	622.4	2.7	12.3	16.4	0	5942.3
MAY	748.0	7.1	1.97	23468	385.2	4757.9	0	715.7	1.3	31.0	40.8	304	314.0	1.3	13.4	8.1	0	5391.9
JUNE *2	503.3	5.3	1.98	6112	138.9	1170.8	503	0	0	0							100.0	1182.3
JULY *2																		
AUG. *1	550.8	6.2	2.04	10795	232.0	2387.2	1	524.7	0	25.1	112.8	100.8	72.1	0.9	4.2	10.8	0.2	2473.4
SEPT. *3	717.1	6.4	2.32	14638	324.0	3460.9	93.3	356.3	0	167.5	187.2	992.8	1898.8	6.8	28.7	51.7	26.9	3505.0
OCT. *4	750.8	6.3	2.42	13962	311.3	3557.1	144.2	302.6	0	304.0	268.8	1868.8	2988.2	13.4	52.5	97.6	19.2	3610.7
NOV.	756.3	5.6	2.49	12482	277.7	3200.0	40.3	532.6	0	183.6	183.2	1667.2	2578.1	13.4	52.1	66.1	5.3	3213.5
DEC. *5	718.9	6.3	2.23	16650	312.5	4614.5	718.5	0	0	0							100.0	4683.4
SUM	7645.7	6.13	1.97	206288	3566.0	46115.6	1602.5	5088.2	29.2	926.0	963.2	7625.6	9898.1	3.7	16.5	25.97	20.96	50380.7

NOTES: Explanation on following page.

NOTES ON SWIFT CURRENT (Electronic A) 1982

*1 Turbine restarted on August 5, 1982.

*2 Turbine not operating.

*3 Turbine shutdown on September 23, 1982.

*4 Turbine restarted on October 7, 1982.

*5 Turbine not operating.

*6 Estimated performance reported was in error.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL SWIFT CURRENT

CUT IN WIND SPEED 6.60
CUT OUT WIND SPEED 15.65 (unless otherwise noted)

YEAR: 1983				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE						ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME	ACTUAL GEN. % OF EST. GEN. TIME	DOWN TIME % OF TOTAL TIME PERIOD	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD	AVERAGE WIND SPEED	K	AVAIL. WIND ENERGY BETZ LIMIT	EST. GEN. TIME	EST. OUTPUT ENERGY	DOWN TIME	STOP TIME	IDLE TIME	ACTUAL GEN. TIME	ACTUAL INPUT ENERGY	ACTUAL OUTPUT ENERGY						
	HR	M/S		KW-HR	HR	KW-HR	HR	HR	HR	HR	KW-HR	KW-HR	KW-HR	%	%	%	%	KW-HR
JAN. *1	711.9	6.5	1.75	23226	336.9	5118.6	711.9	0	0	0	0	0	0	0	0	0	100.0	5749.5
FEB.	670.6	5.2	1.63	12814	228.9	2724.0	0.1	469.5	0	203.3	114.4	1881.6	2494.0	14.7	72.4	89.1	0.0	3021.1
MAR. *2	532.7	6.3	2.42	10408	263.2	2598.3	5.5	448.2	0	290.4	254.4	2048.8	2262.5	19.7	78.9	110.3	0.7	2618.1
APR.	598.4	6.4	2.21	12404	276.7	3016.5	0.4	*3	*3	344.5	236.0	2760.8	2930.0	22.3	91.5	124.5	0.1	3095.7
MAY *4	642.4	6.4	1.73	15240	258.9	2970.0	0.6	*3	*3	258.2	254.4	2095.2	2445.7	13.8	70.5	99.7	0.1	3361.3
JUNE	699.2	7.0	2.27	17522	362.7	4217.0	0.4	*3	*3	336.5	194.4	2957.6	3429.6	16.9	70.1	92.8	0.1	4411.4
JULY	695.5	6.3	2.09	12889	296.7	2888.1	5.4	*3	*3	241.4	227.2	802.4	2057.4	6.2	27.8	81.4	0.8	2986.5
AUG.	626.3	6.2	1.96	12218	280.7	2621.7	0	*3	*3	220.4	194.4	1464.0	1951.3	12.0	55.9	78.5	0.0	2742.5
SEPT *5	779.9	7.1	1.87	25458	396.3	5334.9	0	*3	*3	400.0	264.0	4220.8	4902.3	16.6	79.1	101.0	0.0	5752.0
OCT. *5	693.9	6.7	2.35	14290	362.3	3359.9	0	*3	*3	393.9	258.4	2518.4	3218.8	17.6	75.0	108.7	0.0	3386.0
NOV. *5	712.9	5.7	1.95	12709	278.2	3066.7	0	*3	*3	265.2	278.4	1926.4	2659.4	15.2	62.8	95.3	0.0	3081.6
DEC. *5	763.7	7.0	2.09	21417	414.0	5278.2	0.5	*3	*3	388.3	157.6	4484.8	4992.5	20.9	85.0	93.8	0.1	5440.1
SUM	8197.4	6.4	1.93	190595	3755.5	43193.9	724.8	917.7	0	3342.1	2433.6	27160.8	33343.5	14.3	62.9	89.0	8.8	45645.8

NOTES: Explanation on following page.

NOTES - SWIFT CURRENT 1983

*1 Turbine was not in operation.

*2 Total time short approximately 10 days. Anemometer problems were noted on data sheets for this period.

*3 The clock control logic was altered causing both "stop" and "idle" time to be recorded on the "idle" time clock. As a result, "idle" and "stop" time can no longer be calculated.

*4 Total time short approximately 2 days. Maintenance was carried out during this time.

*5 Turbine cutout limit raised to 17.88 m/s (40 mph).

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL SWIFT CURRENT

CUT IN WIND SPEED 6.60 m/s
CUT OUT WIND SPEED 17.88 m/s

YEAR: 1984				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.	693.6	6.6	2.10	18157	352.8	4539.9	0	*1	*1	351.5	112.0	3552.0	4384.9	19.6	78.2	99.6	0.0	4117.9
FEB.	695.3	6.8	2.21	17400	344.4	3995.4	0.2	*1	*1	324.1	257.6	2784.0	5550.8	16.0	69.7	94.1	0.0	3805.6
MAR.	778.5	6.4	2.24	15516	365.1	3742.3	0	*1	*1	398.5	235.0	2277.6	4161.4	14.7	60.9	109.1	0.0	3493.4
APR.*2	616.4	7.6	1.98	23299	333.8	5493.6	72.0	*1	*1	331.7	185.6	4532.0	5651.3	19.6	82.5	99.4	11.7	5491.9
MAY	765.3	7.8	1.89	32250	424.8	6267.3	0	*1	*1				4013.8	12.3	63.5	87.1	0.0	6983.7
JUNE*3	810.5	6.1	1.59	17946	310.2	3533.7	810.4	*1	*1	0.1	1.6	0.0	525.9	0.0	0.0	0.0	100.0	3828.8
JULY*4	663.1	5.7	1.79	11189	224.6	2589.8	663.1	*1	*1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2615.1
AUG.*4	768.1	6.6	1.85	18446	366.2	3872.2	768.1	*1	*1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	4149.3
SEP.*4	719.9	6.2	2.02	14820	312.2	3586.9	719.1	*1	*1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	3611.5
OCT.*5																		
NOV.	820.5	4.5	1.67	12148	247.1	2724.9		*1	*1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2743.6
DEC.	664.1	7.6	2.16	24341	396.9	5295.7	348.1	*1	*1	200.8	131.2	2219.2	2296.0	9.1	41.9	50.6	52.4	5501.4
SUM.	7995.3	6.5	1.84	205512	3678.1	45641.7	3381			1979.5	1225.4	19356.8	26584.1	9.4	42.4	53.8	42.3	46342.2

NOTES: Explanation on following page.

NOTES ON SWIFT CURRENT 1984

*1 The clock control logic was altered causing both "stop" and "idle" time to be recorded on the "idle" time clock. As a result "stop" and "idle" time can no longer be calculated.

*2 Down time this month due to guy tension problems. This problem has since been corrected.

*3 Turbine shutdown due to the failure of the lower main thrust bearing at the base of the turbine. No power generation took place during the month of June, 1984.

*4 Turbine shutdown pending the repair of the lower main thrust bearing.

*5 Data lost due to an accidental power failure.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL SWIFT CURRENT

CUT IN WIND SPEED 6.60 m/s
CUT OUT WIND SPEED 17.88 m/s

YEAR: 1985				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE										
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.	719.9	7.6	2.24	26513	426.4	6058.5	0.0	*1	*1	432.0	180.0	5608.0	5804.6	21.2	92.6	101.3	0.0	6166.5
FEB.	672.2	7.3	2.18	23173	378.0	5235.0	84.9	*1	*1	238.1	158.4	1933.6	2241.6	8.3	36.9	63.0	12.6	5297.9
MAR.	743.6	7.0	2.61	19550	397.3	4657.8	0.0	*1	*1	393.9	251.2	3666.4	4109.5	18.8	78.7	99.1	0.0	4659.6
APR.	720.0	7.5	2.03	26021	414.3	5218.1	0.0	*1	*1	441.9	216.8	4502.4	5083.2	17.3	86.3	106.7	0.0	5618.0
MAY	815.9	6.9	1.75	24678	376.3	4871.4	46.5	*1	*1	221.3	134.4	2091.2	2528.8	8.5	42.9	35.7	5.7	5320.3
JUNE	654.9	7.4	1.76	24925	320.6	4485.7	0.0	*1	*1	271.9	192.0	2700.0	3149.2	10.8	60.2	84.8	0.0	5144.6
JULY	715.2	6.1	1.86	12866	276.9	2882.2	0.0	*1	*1	250.7	241.6	1676.8	2218.7	13.03	77.0	90.5	0.0	2941.7
AUG.	822.8	6.5	1.77	19355	351.3	4201.8	0.0	*1	*1	348.9	224.8	3163.2	3850.3	16.34	75.28	99.23	0.0	4440.9
SEP.*2	671.8	7.4	2.05	21392	378.5	4808.6	192.0	*1	*1	278.6	131.4	3084.0	3518.0	14.42	64.14	73.61	28.6	5065.6
OCT. *3	722.3	7.7	2.45	23415	465.3	5590.8	456.0	*1	*1	152.3	79.2	1599.2	1915.9	6.83	28.6	32.73	63.1	5732.0
NOV.	792.5	6.1	2.39	15599	366.4	3775.9	0.0	*1	*1	235.3	177.6	2203.2	2579.6	14.12	58.3	64.2	0.0	3777.2
DEC.	696.1	7.7	1.94	29648	393.3	5538.0	0.0	*1	*1	343.4	246.4	3629.6	4213.9	12.24	65.54	87.3	0.0	6049.2
SUM.	8747.2	7.07	1.95	267135	4544.6	57323.8	779.4			3608.3	2233.8	35857.6	41213.3	13.42	62.55	79.40	8.81	60213.5

NOTES: Explanation on following page.

NOTES ON SWIFT CURRENT

*1 Due to malfunctioning clocks, stop and idle time values are unavailable.

*2 Turbine was shut down due to faulty rotor belt. Therefore, 8 days of down time to be shown on this months report.

*3 The turbine was down due to a broken drive belt until October 22, 1985, hence the large down time.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL SWIFT CURRENT COMPENSATED

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 17.88 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. MONTH OF RECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.	767.1	7.7	2.02	32187	457.0	7199.2	0.0	*1	*1	399.4	249.6	4334.4	5500.2	13.5	60.2	87.4	0.0	7720.2
FEB. *2	672.3	5.1	1.81	12949	238.7	3278.8	72	*1	*1	131.9	89.6	1431.2	2872.9	11.0	43.7	55.3	10.7	3294.6
MAR.	695.9	7.1	1.85	23713	344.9	5026.0	695.9	-	-	-	-	*4	-	0.0		0.0	100	5334.6
APR. *3	-	-	-	-	-	-	-	-	-	-	-	*4	-	0.0		0.0	-	-
MAY *3	1487.9	7.3	2.29	43937	844.0	11143.3	1487.9					-	-	0.0		0.0	100	11264.4
JUNE *5	719.7	6.5	2.00	15485	339.8	3687.9	555.6	*1	*1	53.0	35.2	386.4	511.9	2.5	10.5	15.6	77.2	3765.9
JULY *6	692.7	6.2	1.88	13740	266.3	3103.4	0.0	*1	*1	258.9	200.8	2512.0	3182.8	18.3	80.9	97.2	0.0	3154.9
AUG.	767.9	5.5	1.88	9666	233.9	1943.8	0.0	*1	*1	130.4	170.4	656.0	1029.7	6.8	33.7	55.8	0.0	1955.5
SEP.	887.8	6.1	1.76	17337	333.1	3541.5	0.0	*1	*1	319.0	338.4	2540.8	3463.5	14.7	71.7	95.8	0.0	3713.2
OCT.	600.0	6.4	2.12	11829	281.4	2764.3	0.0	*1	*1	274.5	177.6	1682.4	2379.2	14.2	60.9	97.5	0.0	2802.7
NOV.	679.4	7.1	2.11	21494	368.2	5444.1	0.0	*1	*1	287.7	180.8	3639.2	4377.4	16.9	66.8	78.1	0.0	5529.0
DEC.	832.1	7.9	2.51	30474	551.0	7595.8	0.0	*1	*1	507.1	248.0	5260.0	6786.8	17.3	69.2	92.0	0.0	7767.5
SUM.	8802.9	6.7	1.96	232811	4258.3	54728.1	2811.4	*1	*1	2361.9	1690.4	22442.4	30204.4	9.6	41.0	55.5	31.9	52536.6

NOTES: Explanation on following page.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL SWIFT CURRENT

CUT IN WIND SPEED 6.6 m/s
CUT OUT WIND SPEED 17.88 m/s

YEAR: 1986				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE											
① APPROX. ONTH F ECORD	② TOTAL TIME IN PERIOD h	③ AVERAGE WIND SPEED m/s	④ K	⑤ AVAIL. WIND ENERGY BETZ LIMIT kWh	⑥ EST. GEN. TIME h	⑦ EST. OUTPUT ENERGY kWh	⑧ DOWN TIME h	⑨ STOP TIME h	⑩ IDLE TIME h	⑪ ACTUAL GEN. TIME h	⑫ ACTUAL INPUT ENERGY kWh	⑬ ACTUAL OUTPUT ENERGY kWh	⑭ ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA kWh	⑮ ACTUAL OUTPUT ENERGY % OF AVAIL. WIND ENERGY %	⑯ ACTUAL OUTPUT ENERGY % OF EST. OUTPUT ENERGY (NO DOWN TIME) %	⑰ ACTUAL GEN. TIME % OF EST. GEN. TIME %	⑱ DOWN TIME % OF TOTAL TIME IN PERIOD %	⑲ ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUT OUT WIND SPEED kWh
JAN.	767.1	7.7	2.02	32187	457.0	6450.9	0.0	*1	*1	399.4	249.6	4334.4	5018.1	13.5	67.2	87.4	0.0	6917.7
FEB. *2	672.3	5.1	1.81	12949	238.7	2988.9	72	*1	*1	131.9	89.6	1431.2	2618.0	11.0	47.9	55.3	10.7	3003.3
MAR.	695.9	7.1	1.85	23713	344.9	4662.3	695.9	-	-	-	-	*4	-	0.0	0.0	0.0	100	4948.6
APR. *3	-	-	-	-	-	-	-	-	-	-	-	*4	-	0.0	0.0	0.0	-	-
MAY *3	1487.9	7.3	2.29	43937	844.0	10967.8	1487.9					-	-	0.0	0.0	0.0	100	11087.0
JUNE *5	719.7	6.5	2.00	15485	339.8	3687.9	555.6	*1	*1	53.0	35.2	386.4	511.9	2.5	10.5	15.6	77.2	3765.9
JULY *6	692.7	6.2	1.88	13740	266.3	3137.9	0.0	*1	*1	258.9	200.8	2512.0	3218.2	18.3	80.1	97.2	0.0	3190.0
AUG.	767.9	5.5	1.88	9666	233.9	1959.5	0.0	*1	*1	130.4	170.4	656.0	1038.0	6.8	33.5	55.8	0.0	1971.3
SEP.	887.8	6.1	1.76	17337	333.1	3499.5	0.0	*1	*1	319.0	338.4	2540.8	3422.4	14.7	72.6	95.8	0.0	3669.2
OCT.	600.0	6.4	2.12	11829	281.4	2673.4	0.0	*1	*1	274.5	177.6	1682.4	2301.0	14.2	62.9	97.5	0.0	2710.5
NOV.	679.4	7.1	2.11	21494	368.2	5087.9	0.0	*1	*1	287.7	180.8	3639.2	4091.0	16.9	71.5	78.1	0.0	5167.3
DEC.	832.1	7.9	2.51	30474	551.0	6936.8	0.0	*1	*1	507.1	248.0	5260.0	6198.0	17.3	75.8	92.0	0.0	7093.6
SUM.	8802.9	6.7	1.96	232811	4258.3	52052.8	2811.4	*1	*1	2361.9	1690.4	22442.4	28417.4	9.6	43.1	55.5	31.9	53524.4

NOTES: Explanation on following page.

NOTES ON SWIFT CURRENT 1986

*1 Due to malfunctioning clocks, stop and idle times are unavailable.

*2 Due to technical difficulties, two readings on the "24 Hour" histogram were entered erroneously. Therefore, corrected values had to be substituted in bins 10 and 11. Also, turbine data will be low due to a malfunction in one of the systems fuse boxes.

*3 Data dated for May covers a two month period since the recorder was not read at the end of April.

*4 Turbine fuse box failure. Turbine not running.

*5 The turbine was re-started on June 25 or 26. The "actual performance" data is based on a seven day period.

*6 The 24-hour histogram was missing 27.8 hours of data when compared with the reported calendar period (3.9%). The turbine-coupled histogram exactly matched the reported calendar period.

MONTHLY AVERAGE WIND SPEED
AND WEIBULL PARAMETER "K"
AS CALCULATED FROM CONTINUOUSLY
RUNNING WIND HISTOGRAM RECORDER

SITE NAME: SWIFT CURRENT

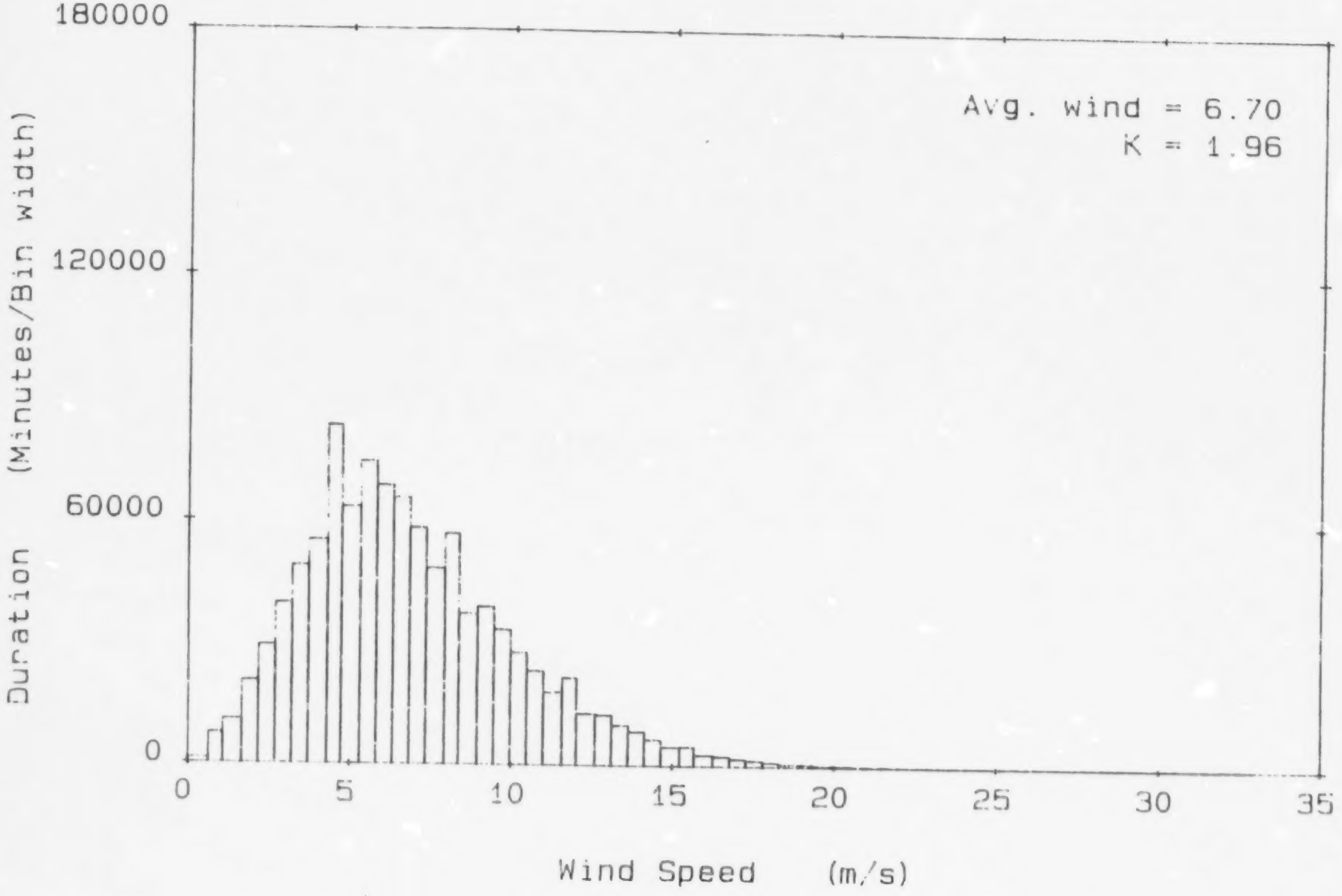
YEAR: 1986

APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January	767.1	7.7	2.02	0.013
February *1	672.3	5.1	1.81	0.039
March	695.9	7.1	1.85	0.023
April	-	-	-	-
May *2	1487.9	7.3	2.29	0.009
June	719.7	6.5	2.00	0.020
July*3	692.7	6.2	1.88	0.029
August	767.9	5.5	1.88	0.038
September	887.8	6.1	1.76	0.037
October	600.0	6.4	2.12	0.017
November	679.4	7.1	2.11	0.013
December	832.1	7.9	2.51	0.004
YEAR	8802.9	6.7	1.96	0.020

Notes: *1 Due to technical difficulty, two readings on the "24 Hour" histogram were entered erroneously. Therefore, corrected values had to be substituted in bins 10 and 11.

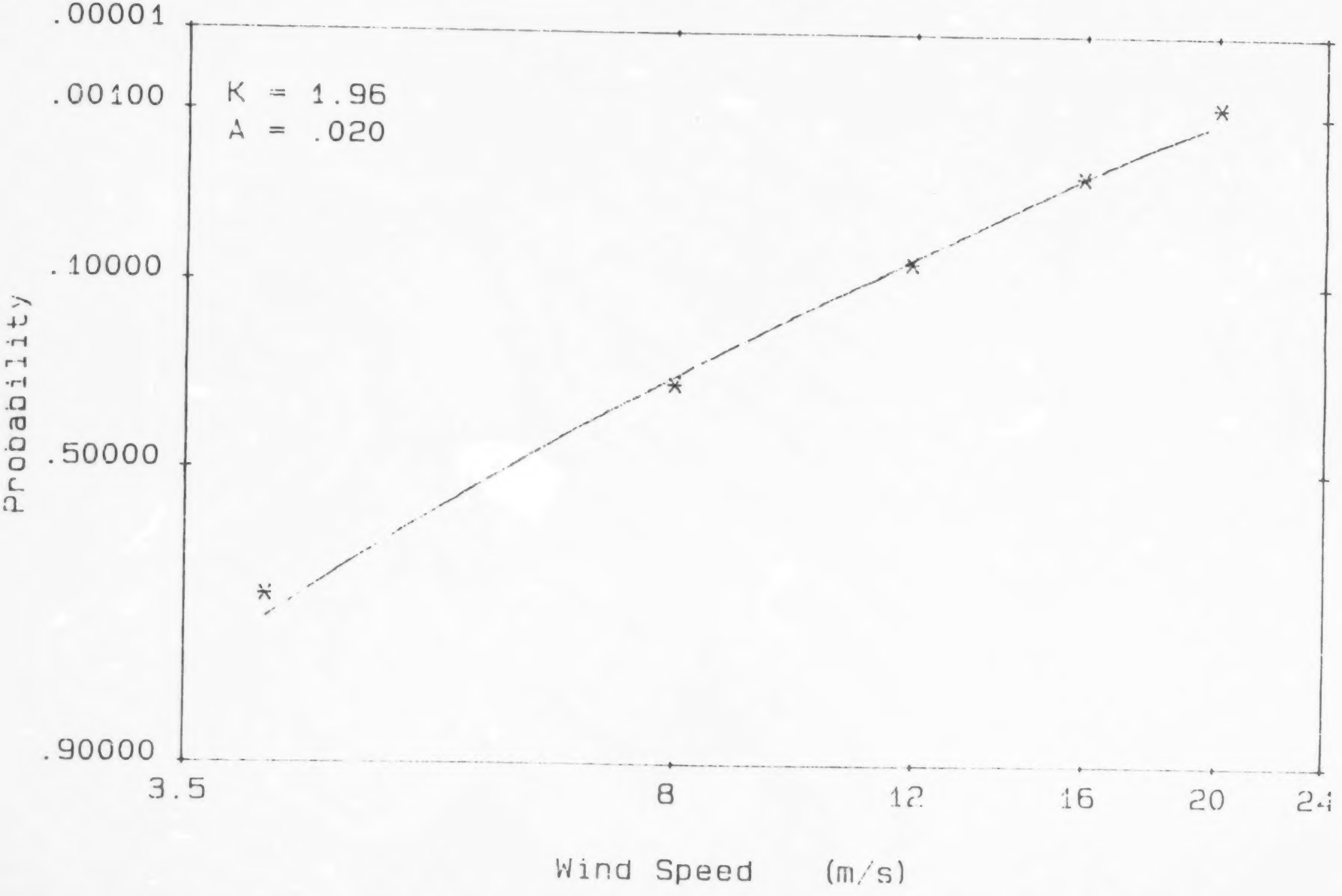
*2 Data dated for May covers a two month period since the recorder was not read at the end of April.

*3 The 24-hour histogram was missing 27.8 hours of data when compared with the reported calendar period (3.9%).



SWIFT CURRENT

January 3 1986 to January 5 1987

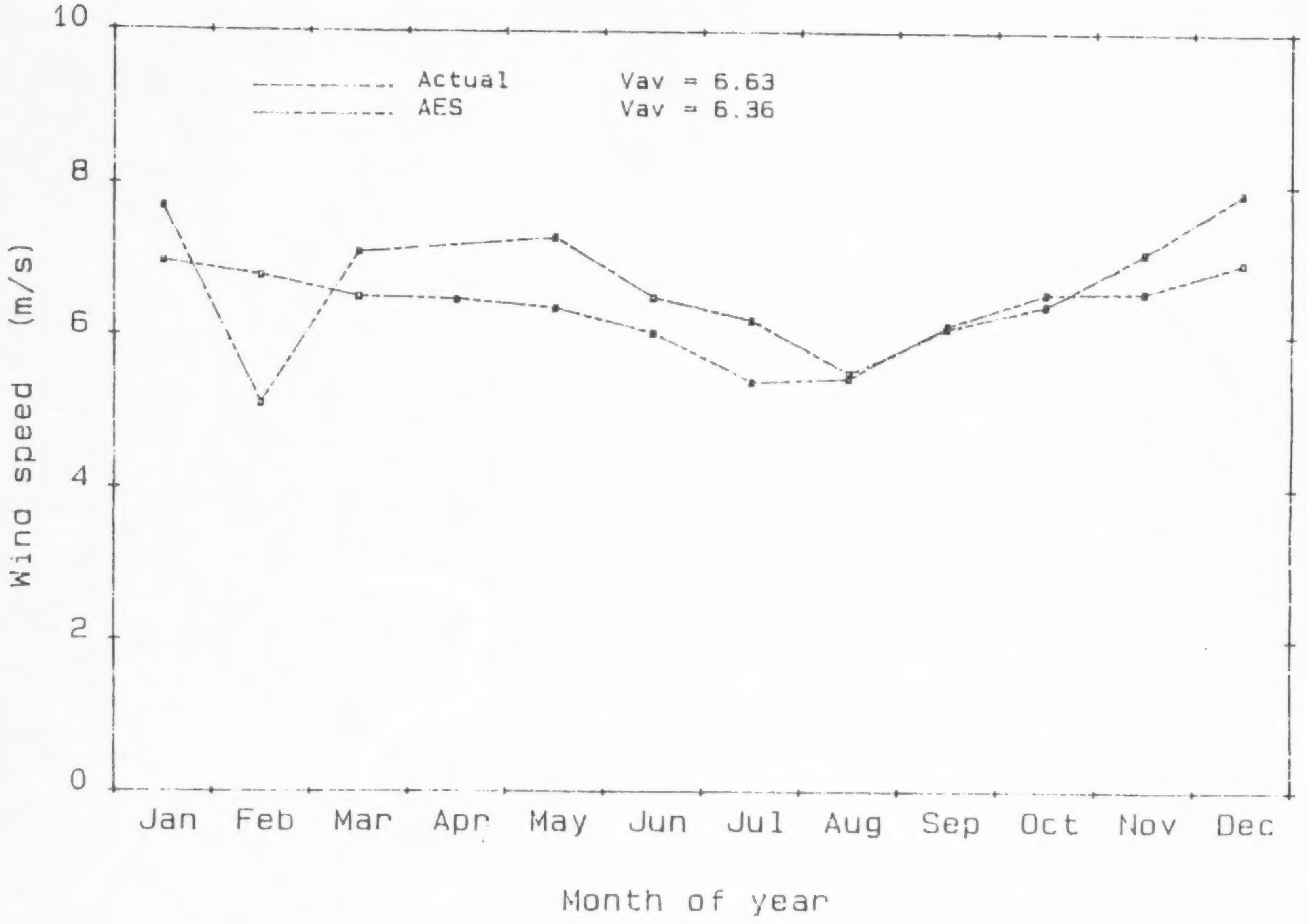


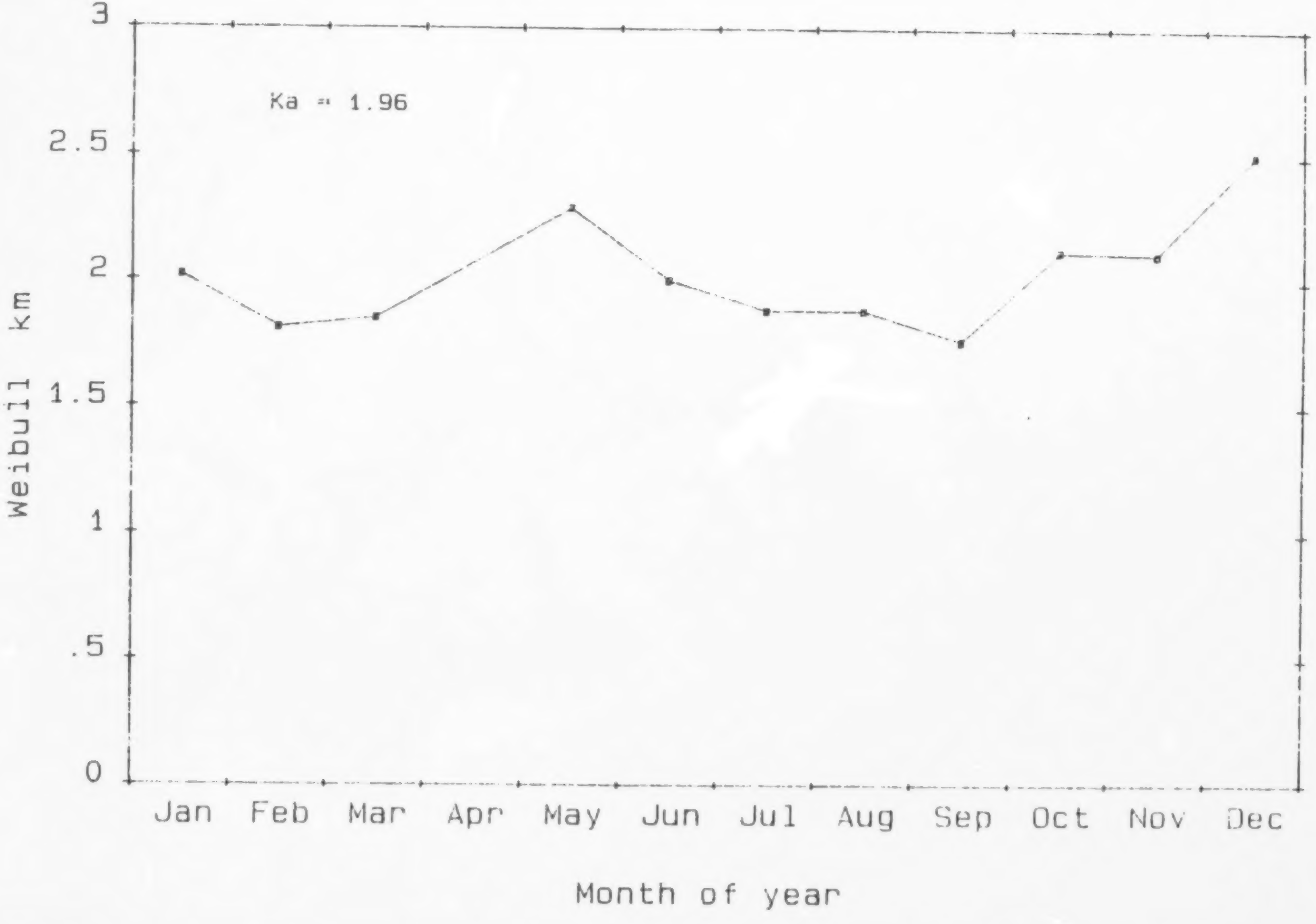
SWIFT CURRENT

January 3 1986 to January 5 1987

COMPARISON OF AVERAGE WIND SPEEDS

SWIFT CURRENT 1986



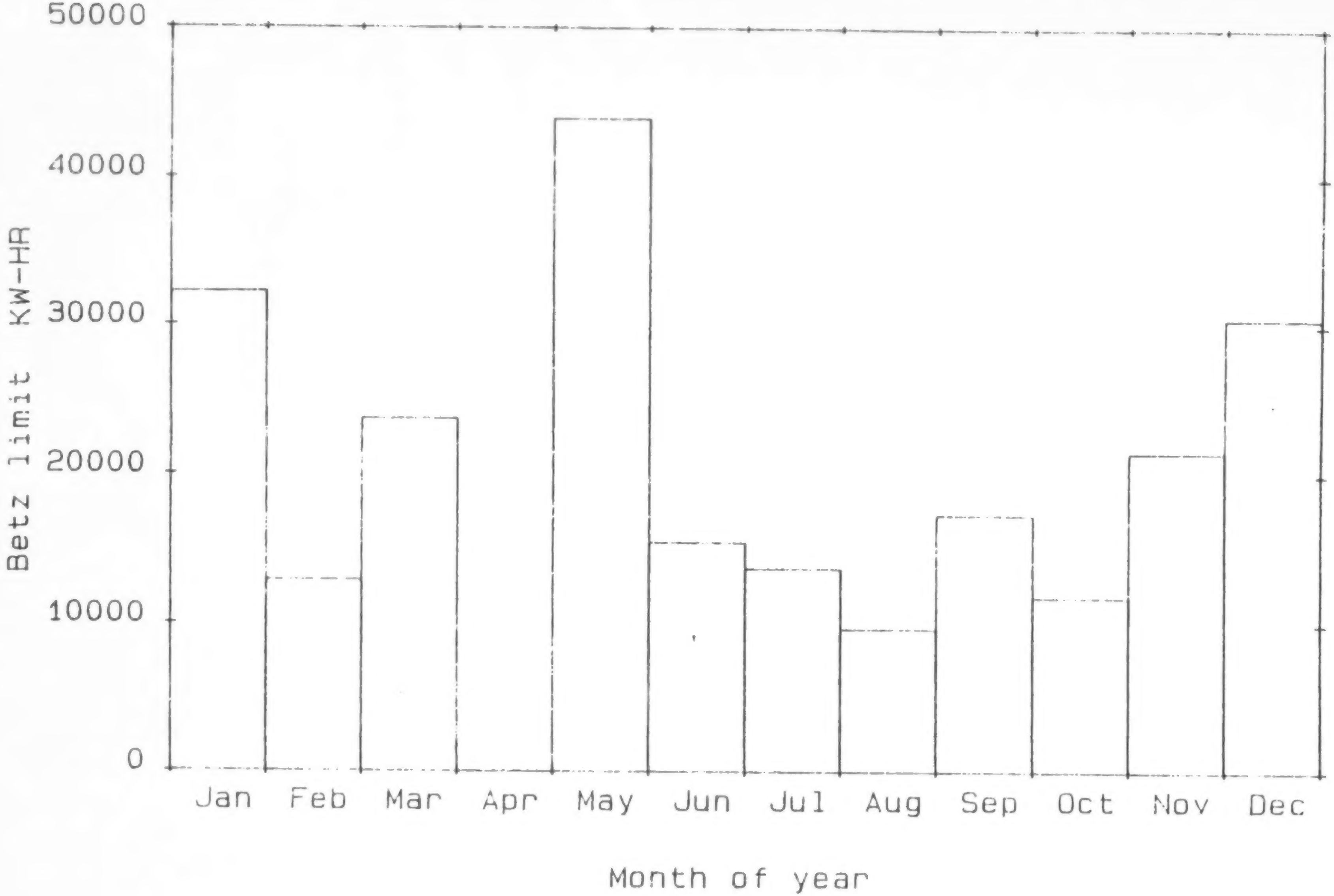


WEIBULL PARAMETER km VS month

SWIFT CURRENT 1986

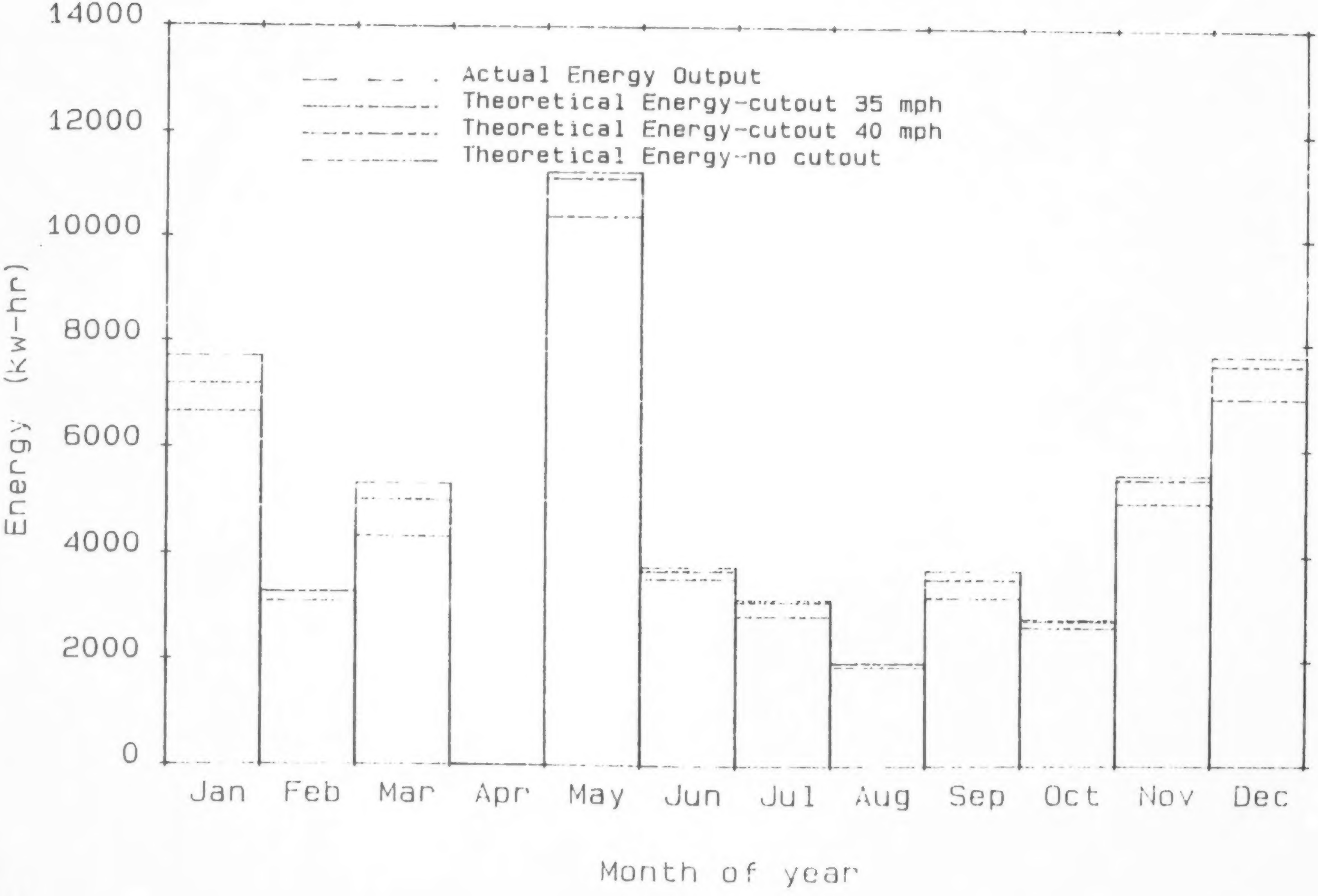
BETZ LIMIT KW--HR

SWIFT CURRENT 1986



TURBINE THEORETICAL ENERGY KW-HR

SWIFT CURRENT 1986



VAWT SYSTEM NOTES: SWIFT CURRENT

The following notes summarize turbine operational problems and failures as reported to T E S Limited from site the operator's data sheets.

Nov, 1980	A down time meter was installed to report the time during which the turbine was out of service.
May, 1981	During a regular site visit it was noticed that the spoilers would not remain latched. After several attempts to latch the spoilers and start the turbine, the turbine was shut down and the slip rings at the top of the rotor were cleaned. The wind histogram recorder and anemometer were changed.
Jun, 1981	The turbine was shut down this month during which time the overspeed system was checked. The set point ammeter was found to be reading incorrectly.
Jul, 1981	During the month of July, 1981 the tension meters were damaged due to a power failure. This problem caused frequent trips to the turbine. Repairs were made to the turbine and the instrumentation. It was reported that the south guy monitor was destroyed and that the north monitor was the only one operational.
Aug, 1981	The cut-out limit on the turbine was raised from 35 to 37 mph to compensate for the difference in measured and mid-rotor wind speeds.
Sep, 1981	The spoilers caused more problems this month. They were repaired on September 14, 1981. At this time hairline cracks on the rotor were found. Further investigation found that the cracks were not significant as only the galvanized surface had cracked.

Oct, 1981	The turbine was shut down.
Nov, 1981	Frosting on the anemometer caused lower readings than actual. The turbine remained shut down during the month.
Jan, 1982	On January 21, 1982 the turbine was restarted. Checks to the control and safety systems were performed on January 25, 1982. It was found that the guy tension indicators were not operating as they should. The spoilers were being deployed when they shouldn't.
Feb, 1982	The spoilers continued to cause problems this month. A squeak was detected at low wind speeds.
Mar, 1982	The northeast guy monitor was found to be reading incorrectly. This problem could be temporarilly cured by pressing the calibrate button on the monitor. The spoilers continued to cause problems. A new logic card was installed for the failed northeast guy, however this did not result in a correction of the problem. It was found that by tapping the DC power box the guy monitor would read correctly. Icing caused the turbine to trip on occasion.
Apr, 1982	The system was shut down so that the bearings could be greased. The spoilers continued to cause difficulties which resulted in turbine shut downs. Some work was done on the guy tensions to prevent them from bouncing. Glitches in the tension monitoring caused several trips.
May, 1982	Spoiler problems continued. The turbine was shut down pending repair to the spoilers.

Aug, 1982 The turbine was restarted. Several guy tension trips did not cause the turbine to shut down as they should. The spoilers prevented the rotor from reaching operational speed as they would deploy at low speeds. The turbine was shut down to resolve some of these problems. The problem with the spoilers was found to have been as a result of a wiring problem in the logic of the control system. The tachometer was found to be reading incorrectly and this was inspected. It was found that the bearings had siezed. These were replaced and the tachometer was made functional. A spare tachometer was recieved from Holyrood.

Sep, 1982 The guy tensions were adjusted. The turbine was shut down on September 20, 1982 to do a system and safety check. The turbine was restarted shortly after.

Oct, 1982 The electronics which were previously not operating were repaired and the system was rechecked. The turbine was restarted on October 7, 1982. The idle time clock was found to be inoperative. The slip rings at the top of the tower were cleaned.

Nov, 1982 Excessive guy bounce caused the turbine to be shut down. At this time the strain gauge amplifiers were installed. The 15 volt power supply was replaced. The turbine was restarted after the work was completed. During the month icing on the blades caused extra drag and would sometimes cause the control system to shut the turbine down. The turbine was stopped for a period of three days in an attempt to melt the ice. During this time the guy monitors were calibrated.

Dec, 1982	The spoilers deployed due to rotor overspeed trips. It was noted that the apparent reason for the overspeed was that the generator was not being subjected to any load.
Jan, 1983	On January 21, 1983 the spoilers were adjusted and the digital tachometer was repaired. The turbine would not start as the brakes would not release. The transformer was found to be faulty.
Feb, 1983	Frosting on the control anemometer caused it to read lower wind speeds than the actual. For this reason the turbine would not start. The anemometers were cleared of ice and the turbine started. A trip caused the turbine to shut down as a result of a faulty guy tension reading. The trip had to be reset by installing a simulated tension gauge. Problems were caused by ice on the blades of the turbine.
Mar, 1983	Icing on the blades of the rotor caused some down time. Some work on the tension meters was performed.
Apr, 1983	The turbine was shutdown while work on the logic system was carried out. The circuit controlling the idle time meter was repaired. Brake pads were adjusted.
May, 1983	The turbine was shut down to clean the slip rings and set the guy tensions. A broken wire from the recorder anemometer was repaired.
Jun, 1983	The brake pump overheated and tripped.
Jul, 1983	More trips from the brake pump occured. The tachometer bearings were replaced.

Sep, 1983	The turbine was found tripped on several occasions this month due to the pump overheating. Bearings in the anemometers were replaced and the digital tachometer fixed.
Oct, 1983	Trips occured from faults in the guy tension system. The cut-out wind speed was raised from 40 mph to 42 mph to account for the difference of wind speeds at the mid height of the rotor and the actual position of the control anemometer.
Dec, 1983	Icing was apparent on the blades of the turbine and the anemometer cups.
Jan, 1984	Due to excessive wind gusts the turbine was shutdown.
Feb, 1984	The cut-out limit was raised from 42 mph to 52 mph for a short period during the month to allow for specialized tests. Some shut down time occured as a result of work being performed on the main power lines.
Apr, 1984	A malfunction in the brake release system was found. This was repaired when a broken wire was found. A distinctive rattle was heard coming from the top of the rotor.
May, 1984	The pump overheated causing the turbine to trip. A grate on the floor of the pump room was installed in an attempt to dissipate some of the heat.
Jun, 1984	The lower main thrust bearing was found damaged. The turbine was shut down pending repairs.

Jul, 1984	The turbine remained out of service pending repairs to the thrust bearing.
Aug, 1984	Turbine not in service.
Sep, 1984	Turbine not in service.
Oct, 1984	Repairs to the turbine continued. The power to the wind histogram recorders was accidently discontinued, causing the data for the month to be lost. When power was connected, data collection resumed.
Nov, 1984	The turbine did not operate during the month as maintenance tasks continued.
Dec, 1984	Maintenance tasks were completed and the turbine returned to service on December 20, 1984.
Jan, 1985	The turbine performed well during the month.
Apr, 1985	No turbine faults occurred during the month VAWT operating well.
Sep, 1985	The site inspector indicated that the turbine rotor belt failed and had to be replaced. Therefore, the turbine had to be shut down until a replacement belt arrived.
Oct, 1985	Rotor belt was replaced on October 22, 1985.
Nov, 1985	The site inspector reports a high number of guy tension shutdowns due to rapid decreases in ambient temperature.
Jan, 1986	The site is functioning without incident.

Feb, 1986	It was discovered, on this date, that one of the three fuse blocks and holders (with copper strips rather than fuses) had overheated and physically burned up. This resulted in the loss of one phase and therefore, the turbine is inoperable. It was also noted that line fault shutdown event counter did not register this failure. As of March 21, 1986 the fuse box had not been repaired and they were still awaiting delivery on parts.
May, 1986	Fuse blocks replacement still not available. As of June 2, turbine was still shutdown.
June, 1986	Turbine repaired and on-line on June 25 or 26.